

## BLACK PEPPER (*PIPER NIGRUM* L.) BACTERIAL DECONTAMINATION BY STERILIZATION AND MICROWAVE TREATMENTS

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### ABSTRACT

Microbial number reduction in spices through various treatments represents a necessity considering possible changes which may occur during spices' storage and application in food resulting in public health risk. The present study was conducted in order to examine the effects of sterilisation and microwave irradiation treatments on total mesophilic aerobic bacteria (TMAB) and bacterial spore content reduction in black pepper. Treatments applied were: sterilisation at 130 °C during 30, 60 and 90 min; and microwave irradiation at a power level of 600 W during 1.5, 3, and 5 min. Prolongation of the sterilisation treatment expressed positive influence on TMAB and bacterial spore reduction in black pepper. Compared to the sterilisation, microwave irradiation treatment exhibited better results in terms of black pepper decontamination. Maximal decontamination regarding TMAB and bacterial spore was achieved in black pepper samples treated with microwave irradiation during 3 min. The present results suggest that microwave irradiation could be applied in black pepper decontamination considering better effectiveness compared to the sterilisation treatment.

Keywords: black pepper; drying; microwave irradiation; bacterial decontamination;

### 1. INTRODUCTION

As the oldest and one of the most important spices valuable for its distinctive odour and flavour, pepper is the most frequently used and imported spices in the EU [1]. Despite pepper's contribution to overall food sensorial properties, the main drawback of pepper and generally spices usage is their microbiological contamination. The contamination may occur during harvest, even drying, which often begins in small-scale farms if the proper precaution measures are not taken [2]. Although spices are non-perishable commodities, considering their low moisture contents, dry stress resistant microorganisms such as bacterial spores or some types of Salmonella still persist. The corresponding microorganisms have the ability to grow and multiply quickly to effective and toxic levels when they are introduced to a suitable environment such as water-rich food products with available nutrients. Considering this aspect, the spices addition in ready-to-eat foods represents an arising problem since these types of products are not subjected to any heat treatments [3]. Furthermore, contaminated spices addition besides product's shelf-life shortening caused by spoilage also induced the development of foodborne illness and intoxications in several European countries [4].

Microorganisms that could be found in pepper are toxigenic moulds and yeasts as well as human pathogens such as the spore-forming *Bacillus cereus*, *Clostridium perfringens* and Salmonella [5]. Pepper's high contamination level and high microbial load with viable counts greater than  $10^7$  CFU g<sup>-1</sup>, from which the most numerous are aforementioned spore-forming bacteria, are unfavourable leading to significant problems in export [6]. Commonly used treatments for the microorganisms' inactivation in pepper are steam sterilisation, gamma irradiation and fumigation with ethylene oxide [7]. Steam sterilisation requires an additional drying step mining additional energy and potential recontamination of the product as well as possible colour and aroma deterioration and volatile compounds content reduction. Regarding efficiency, fumigation and gamma irradiation are more efficient compared to steam sterilization especially in spices with a high microbial load like pepper [8]. However, considering carcinogen residues formation fumigation with ethylene oxide is suppressed by European Union law while gamma irradiation requires higher initial

investment and safety measures and is accompanied by consumers' mistrust [8]. To overcome the aforementioned technics' drawbacks and address the present-day demands in the quick sterilisation process development, without any post-treatment step required, and possible application on 'in-pack' products microwave treatment should be considered.

Microwave is an electromagnetic wave with a wave-length ranging from 1 mm to 1 m and operating in the frequency range of 300–30000 MHz [9]. In food processing microwave energy is used mainly for its heating properties. The conversion of microwave energy into heat in food occurs mainly due to water presence as a consequence of dipole water molecules rotation with respect to changing electric field with frictional heat production as an outcome. The quick absorption of energy by water molecules causes rapid water evaporation resulting in high food drying rates [10]. Microwaves penetrate directly into the material inducing volumetric heating (from inside out) and providing fast and uniform heating throughout the product. Therefore the main advantages of microwave drying over the conventional drying are warm up time reduction and preservation of the product's natural organoleptic characteristics [11]. Furthermore, due to the convenience and ease handling, microwaves application in spices processing is gaining the research community attention.

The objective of this study was to investigate the antibacterial effect of sterilization and microwave irradiation on the bacteria and bacterial spore reduction in black pepper seed.

## 2. MATERIALS AND METHODS

### 2.1. Materials

Black pepper (*Piper nigrum* L.) seed before all treatments was purchased from Geneza Ltd., Kanjiza, Serbia and stored at 8±1°C until further use.

### 2.2. Sterilization and microwave irradiation treatments

A laboratory dryer (Sutjeska) was used to investigate the effect of sterilisation on the bacterial decontamination of black pepper. The sterilization treatment was conducted on 10 g of black pepper placed on a Petri dish in a single layer at 130 °C during three different time periods (30 min, 60 min, 90 min) (Tab. 1).

*Table 1. Applied black pepper treatments and corresponding conditions*

Sample code	Treatment	Conditions	Equipment
Control	none	-	-
F	Steam Sterilisation Drying Cooling	130°C, 1.2 min 100–105°C, 21 min -2°C, 5 min	Type of VKMI- 2000 sterilising equipment
S30	Sterilisation	130°C, 30 min	Laboratory dryer (Sutjeska)
S60	Sterilisation	130°C, 60 min	Laboratory dryer (Sutjeska)
S90	Sterilisation	130°C, 90 min	Laboratory dryer (Sutjeska)
MW1.5	Microwave irradiation	600 W, 1.5 min	Microwave oven (Samsung M 171FN)
MW3	Microwave irradiation	600 W, 3 min	Microwave oven (Samsung M 171FN)
MW5	Microwave irradiation	600 W, 5 min	Microwave oven (Samsung M 171FN)

Dried samples were allowed to cool to room temperature, packed and used for further microbiological analysis. To investigate the effects of microwave irradiation on the bacterial decontamination of black pepper a domestic microwave oven (Samsung M 171FN) was used. For the treatment, 10 g of black pepper was placed on a Petri dish in a single layer and located at the centre of turntable plate. Samples were exposed to microwave at a power level of 600 W and three different time periods (1.5 min, 3 min, 5 min) (Tab. 1). After microwave treatment, treated samples were allowed to cool to room temperature, packed and used for further microbiological analysis.

### 2.3. Microbiological analysis

The effects of sterilization and microwave irradiation on the bacterial decontamination were evaluated through total plate counts of total mesophilic aerobic bacteria (TMAB) and bacterial spore content of black pepper. Following the sterilization and microwave drying treatments, pepper was aseptically sampled, to exclude subsequent contamination and obtain a realistic insight into the effect of treatment (steam sterilization, sterilization and microwave irradiation) on the present microflora. The sample of pepper after the treatment was placed in a test tube with sterile 0.9% saline solution and homogenized by stirring. The heat treatment in a water bath at 80°C for 10 min was conducted for the wash solution in order to isolate and count the mesophilic spore-forming bacteria. The wash solution was then sequentially diluted (1:10) placed on a plate count agar (PCA, Merck) and incubated at 30°C for 72 h for both TMAB and mesophilic spore-forming bacteria [12]. Colonies of the appeared bacteria were counted and calculated according to the equation (1):

$$N = \frac{c}{(n_1 + 0.1 \times n_2) \times R} \quad (1)$$

where  $c$  represents the sum of all colonies,  $n_1$  represents the number of parallels at first countable dilution,  $n_2$  represents the number of parallels at second countable dilution, and  $R$  represents dilution factor of first countable dilution. Microbial enumerations were expressed as log of colony forming unit per gram of sample (CFU g<sup>-1</sup>).

### 3. RESULTS AND DISCUSSION

The results addressing the sterilisation and microwave treatments efficiency in bacteria and bacterial spore decontamination are presented in Tab. 2 and graphically illustrated in Fig. 1.

*Table 2. Bacteria and bacterial spore number in black pepper samples after sterilisation treatment during 30, 60, and 90 min (S30, S60, S90) and microwave treatment during 1.5, 3, and 5 min (MW1.5, MW3, MW5)*

Sample code	Total mesophilic aerobic bacteria, TMAB (log CFU g <sup>-1</sup> )	Mesophilic spore-forming bacteria (log CFU g <sup>-1</sup> )
Control	5.58±0.62	4.62±0.67
F	5.89±0.49	5.63±0.25
S30	6.64±0.07	6.66±0.04
S60	6.28±0.30	5.96±0.19
S90	5.29±0.19	5.25±0.19
MW1.5	5.31±0.82	4.64±0.44
MW3	3.89±0.89	3.70±0.66
MW5	5.78±0.26	6.08±0.01

The number of TMAB expressed as log of colony forming unit per gram of sample for sterilised and microwave irradiated samples was found to be in the range of 5.29 to 6.64, and 3.89 to 5.78, respectively. An increase in the number of TMAB was observed in samples sterilised during 30 and 60 min (samples S30, S60, Tab. 2) compared to control, probably due to too short time of treatment and smaller reduction of water content inside pepper. Conversely, a decrease in the number of TMAB was detected with the treatment period prolongation to 90 min (Tab. 2, Fig. 1), indicating time of treatment as an important factor in dry sterilization. Considering microwave irradiation treatment, a decrease in the number of TMAB was noted for samples treated during 1.5 and 3 min compared to control and sample sterilized by steam in the factory. Furthermore, prolongation of the microwave irradiation treatment from 1.5 to 3 min induced a decrease in TMAB number for 26% (samples MW 1.5 and MW3, Tab. 2). Similar observation on TMAB number decrease with prolonged exposure time to microwave irradiation was previously reported in literature [7]. However, further prolongation of the microwave irradiation to 5 min induced an increase in TMAB number. A decrease in TMAB number was more pronounced in microwave irradiated black pepper samples compared to sterilized samples.

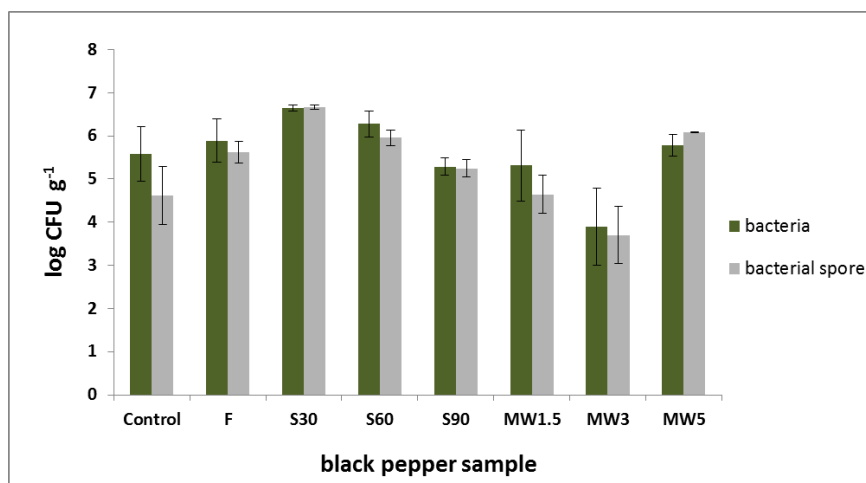


Figure 1. The effects of sterilisation and microwave irradiation treatments on pepper bacterial decontamination. For sample code see Tab. 1.

The bacterial spore number expressed as log of colony forming unit per gram of sample was found to be lower compared to TMAB number in most black pepper samples regardless of applied treatments (Tab. 2, Fig. 1). For sterilized black pepper samples bacterial spore number ranged from 5.24 to 6.66 log CFU g<sup>-1</sup>. Compared to the control sample, an increase in bacterial spore number was noted in sterilized black pepper samples. However, a decrease in bacterial spore number was observed with sterilisation treatment period prolongation from 30 to 90 min (Tab. 2). As regards to microwave irradiation treatment, bacterial spore number in black pepper samples ranged from 3.70 to 6.08 log CFU g<sup>-1</sup>. The bacterial spore number in samples exposed to microwave irradiation for 1.5 and 5 min (samples MW1.5, MW5, Tab. 2) was higher compared to the control sample. Conversely, the lowest bacterial spore number was found in sample treated with microwave irradiation during 3 min. The corresponding sample had bacterial spore number 19% lower than control. Prolongation of microwave irradiation to 5 min led to an increase in bacterial spore number. Comparing the treatments applied, microwave irradiation was more effective in bacterial spore number reduction.

## 4. CONCLUSIONS

The present study investigated the effects of sterilisation and microwave irradiation on bacteria and bacterial spore decontamination in black pepper. Sterilisation treatment at 130 °C during 90 min was the most efficient regarding total mesophilic aerobic bacteria and bacterial spore decontamination considering investigated sterilisation treatments. In general, microwave irradiation treatment proved to be more efficient regarding bacteria and bacterial spore decontamination compared to sterilisation. In black pepper samples treated with microwave irradiation during 3 min maximal decontamination regarding total mesophilic aerobic bacteria and bacterial spore was achieved. However, further prolongation of the microwave irradiation treatment resulted in microbial picture deterioration. The present study showed the greater potential of microwave irradiation treatment in bacteria and bacterial spore decontamination compared to sterilisation. Although further research is needed to establish optimal treatment condition for achieving maximal microbial decontamination, microwave irradiation represents a promising technic for the microbial number reduction in spices.

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## RESEARCH IN THE MECHANIZATION OF BLACK LOCUST RENEWAL AND PLANTING

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### ABSTRACT

Nowadays, the black locust (*Robinia pseudoacacia*) is the most current and the most widely used tree species in Hungary. Due to its penetration and the wide variety of application it's worth to examine the different mechanization options of the reforestation technologies and their costs.

We provided our research in the area of Nyírerdő Nyírségi Erdészeti Zrt.

According to the tests it can be said, that the cost of the reforestation with root ripping is the most favourable and the reforestation or regeneration with planting costs the most. The disadvantage of the regeneration with root ripping is, that after its multiple application it can be observed the significantly degradation of the assortment composition and of the tree utilization income.

Keywords: black locust, mechanization, specific cost, Nyírség

### 1. INTRODUCTION

The black locust (*Robinia pseudoacacia*) is in Hungary the most current and the most widely used tree species in Hungary, especially in the Great Hungarian Plain. More than 24% of all forest area is covered by black locust, this means 451 771,95 hectares and 50 829 689,00 m<sup>3</sup> tree [1]. The most prominent black locust-producing districts are the Nyírség, Cserhát, hills of Gödöllő, sand dunes of Duna-Tisza köz, ridge of Vas-Zala, and the sandy area of the Little Hungarian Plain. Among them, the Nyírség, the Duna-Tisza köze and the Northern Part of Somogy have high quality stands.

The natural spread of the black locust in the US is between 43-35 degrees. The black locust was brought to Hungary around 1710. Initially, it was planted as a park tree and a pathway that surrounds roads. For the purpose of afforestation, the military treasury used it for the first time in 1750 around the fortress of Komárom-Herkály. At the beginning of the 1800s, in the Great Plain they started planting it to fasten the quicksand, then they also created shelter-belts from black locust. Its mass spread in Hungary began in the mid-1800s.

Due to the law, in those areas, which are unsuitable for agricultural operations, 38000 ha black locust forest was planted [2] [3].

Its rapid spread in our country is due to its good adaptation capability, its common and plentiful seed crop, which is the bottom of the seedling cultivation, and due to its granulation capability, and last but not least, due to its large wood yields.

The good physical conditions and the extreme durability of the black locust's wood make it possible for the sawmill industry, furniture industry and for the carpentry industry the widespread usability. The barrel production finds its raw material important, because its wood isn't permeable to water in case of cutting direction either. It's widely used in land-and water building, it's a long lasting fencing panel, vine pole, vine stake. Black locust is used in the production of pulp, fibreboard and chipboard. Recently, laminated-glued holders are made of it. Half the weight of the exploited black locust serves energetic purposes, so it will become firewood. [4].

Due to its widespread and multiple use it's worth to examine the mechanization possibilities of the different reforestation technologies, and their costs.



## 2. THE TECHNOLOGIES OF THE BLACK LOCUST'S PRODUCTION

The renovation of forest areas covered by black locust in domestic practice can basically be done in two ways. In one case, with root tearing, in the other case with full soil preparation after seeding, with planting or with cuttings.

In the latter case, before the propagation material gets into the soil, the following operations have to be done in the area of the depleted forest:

- site clearing,
- stumping,
- stump-pushing,
- flatwork,
- trenching+ smoothing,
- uprooting,
- soil crumbling.

In case of the **site clearing**-which can be done manually or with machines- the branches, bark, pieces of wood will be removed from the area. In case of manual site clearing the gathered felling residue will be put on a stump, to minimize the loss of space, or we pull them together in strips and in heaps, which will stay in that area or will be cut. In case of mechanical site clearing, with the help of a site clearer powered by toothed cutter we will put the slash together either to the edge of the area or into the strips. It's a more preferred solution to use hay horizontal shaft slash chopper, which smash the along the area scattered piece of woods, branches into small pieces and leave them on the area. These small pieces won't bother the other procedures and will serve as a nutrient with time.

In case of soil cultivation the **stumping** essential, because the ploughing and the trenching can't be done because of the stumps in the soil. The stumping is really costly but it's able to reduplicate the afforestation costs. The removal of the stumps will be done by means of machine tools designed for this purpose.

During the **stump-pushing** in the area after the stumping the scattered stumps will be sorted in row. There's no need for this procedure in case of clutching accent stump puller, because the picked-up stumps will be composed in stump –rows. We usually do the procedure with stump-pusher or with bulldozer.

In case the stumps of the area will be sold, this operation can be postponed as well, because this time the stumps will be chipped with special chippers. At this time there will be no stump- rows.

For the uninterrupted continuation of the afforestation works the **flatwork** is essential. Those operations belong here, where we make the area passable for the power machines. As a result of the stumping generated pits will be bury and we smooth the hillocks. The operation of plaining is also an essential process in sand areas, where the dunes should be transformed in such way, that the its slope will be favourable for the machines. We can do the flatwork with blades attached to the tool-machines or we can do it with towed graders.

For **trenching**, the ground is rotated to a depth of 50-70 cm. This operation is carried out by rippers. In many cases with the deep rotation the smoothing is also done. After the rotation the area has not an appropriate quality for the planting or for the sowing, that's why there's a need for smoothing during which we try to smooth the jagged soil surface as smoothly as possible.

On the stumped area, after turning to the surface of the soil or to the roots near the surface have to be removed for the future machine planting and tilling. The **root removal** can be done in two ways. In one case it can be done manually and it has to be done immediately after the turning soil cultivation, in the other case it has to be done mechanically. In the latter case it can be done later. The operation is carried out by a root rake fixed on a power machine. The collected roots have to be removed from the area. In case of doing the stumping not with stump extraction , but with the help of stump driller or stump chipper, then before rotating the area, the root-raking has to be applied , that the larger roots left in the soil don't damage the plough.

The soil crumbling has several advantages. It should be done before planting and sowing, that the seedlings and seeds in the area can be placed in an appropriate structure soil. But it's also suitable for the reducing of weeds, because if we crumble and old weedy ploughing, then the weed will be also worked into the soil. There're currently many machines available for the soil crumbling.

The delivering of the propagating material into the soil can be done by sowing, planting or by planting cuttings.

Sowing with afforestation is preferable to planting, because the seedling numbers will be higher, which will result in faster closure of the stock and a greater natural selection. This afforestation method is closer to the natural reforestation. The sowing requires less work and cost than planting. However, its disadvantage is that in the weediness prone areas the care work has to be done several times, and because of the uncertain seed production there is not always available the right amount of propagating material. The sowing can be done manually or mechanically. The manual sowing is done in areas without partial soil preparation or soil preparation. We put 4-5 seeds into a pit made with the help of hoe, hack, grubbing hoe, and than we cover it. The mechanical sowing can be applied after complete soil preparation.

The **planting** can be also done manually or mechanically. The tools of manual planting can be the spade, hoe, hack, and the planting bar. During planting we have to take it into account the size of the seedlings, and we have to dig pits for the roots of the seedling with the appropriate depth and width. The other method is mechanical planting, which is much faster and has a lower demand of labour, and the afforestation with it is much cheaper.

The black locust has an excellent regeneration ability, especially vegetatively. We take advantage of this ability of the black locust during the **planting cuttings**. The root cutting dates back to the 1980s. Actually, this is also a kind of coppicing. The picked roots of the selected mother trees will be cut into pieces, which can be up to 10-12 cm or 2-4 cm dependig on the thickness of the root. These pieces are placed into the seed furrow in such a way that they're strictly horizontal so that the cuttings are very similar to the coppicing situation after root ripping. This wood-production technology is very rarely used [5].

The black locust is able to sprout from root or from stump as well, but the with root sucker renewed black locust has much better properties than the stump sprout. This is the basis of the reforestation technology made with **root ripping**. The ripping of the black locust's roots near to the soil surface is done by the late help of the machineries' knives.

Since the black locust is very viable and fast growing species, therefore, the nursing of the regrowth should only be carried out in justified cases. The most commonly used care technologies in the locust [6]:

- *Manual in-line hoeing*: Its essence is to free the weed competition after the interrow weeding and to loosen the soil. The operation will be mainly done manually or by hoe.
- *Shoot control*: The suppression of the in the stand undesirable stump sprouts, so that we can provide the appropriate growing space for the slowly growing root suckers. It can be done by axe, or by chain saw at an older age.
- *Cutting off to one leader*: We choose the regrowth with the most appropriate natural qualities to be the leading shoot, and the other ones will be
- *Cutting at base*: The 1 or 2 year-old seedling will be cut at base after reaching the appropriate root size, so we can achieve that the again shooted sprout specimen will grow faster, it will be straighter and will raise less stems with side branches.
- *Chemical weed control*: It's such an in-line weeding activity that we can drive back the weeds with, so that won't mean competition for the seedlings.
- *Mechanical interrow care*: During the procedure we do the interrow soil crumbling and weed control. The operation can be well mechanized, as the machines fit well in the spacing, without damaging the regrowth. The interrow care means very often the „shearing” of the weed with slash chopper.



### 3. THE MACHINES FOR THE BLACK LOCUST'S REFORESTATION TECHNOLOGIES AND THEIR SPECIFIC COSTS IN THE NYÍRSÉG

We did our researches in the area of the Forestry in Nyíregyháza of the NYÍRERDŐ Zrt. We summarized the specific costs of the consecutive work phase and compared them to each other (Table 1, Table 2, Table 3, Table 4). In addition to the specific costs, the table also lists the machines that are used for the particular work phase.

*Table 1. Reforestation technology I.*

<b>Reforestation (with sowing)</b>			
<b>Work phase</b>	<b>Power machine</b>	<b>Machinery</b>	<b>Specific costs</b>
Site clearing	Front-end loader	VT-02	18.000 Ft/ha
Stumping	JCB 4cx front-end loader	Special stump extraction spoon	160.000 Ft/ha
Stump-pushing	T-130	Blade	80.000 Ft/ha
Flatwork	T-130	Blade	50.000 Ft/ha
Trenching +smoothing	T-130	Ripper+disk	80.000 Ft/ha
Uprooting	T-130	Root rake	35.000 Ft/ha
Soil crumbling	T-150	Disk	10.000 Ft/ha
Sowing	MTZ 820.4	Seeder	40.000 Ft/ha
Care	MTZ 820.4	Slash chopper	10.000 Ft/ha
<b>Total</b>			<b>483.000 Ft/ha</b>

*Table 2. Reforestation technology II.*

<b>Reforestation (with planting)</b>			
<b>Work phase</b>	<b>Power machine</b>	<b>Machinery</b>	<b>Specific costs</b>
Site clearing with machine	Front-end loader	VT-02	18.000 Ft/ha
Stumping	JCB 4cx front-end loader	Special stump extraction spoon	160.000 Ft/ha
Stump-pushing	T-130	Blade	80.000 Ft/ha
Flatwork	T-130	Blade	50.000 Ft/ha
Trenching +smoothing	T-130	Ripper+disk	80.000 Ft/ha
Uprooting	T-130	Root rake	35.000 Ft/ha
Soil crumbling	T-150	Disk	10.000 Ft/ha
Planting	John Deer 2250	ERTI planting	80.000 Ft/ha
Care	MTZ 820.4	Slash chopper	10.000 Ft/ha
<b>Total</b>			<b>523.000 Ft/ha</b>

Table 3. Reforestation technology III.

Reforestation (with planting cuttings)			
Work phase	Power machine	Machinery	Specific costs
Site clearing	Front-end loader	VT-02	18.000 Ft/ha
Stumping	JCB 4cx front-end loader	Special Stump extraction spoon	160.000 Ft/ha
Stump-pushing	T-130	Blade	80.000 Ft/ha
Flatwork	T-130	Blade	50.000 Ft/ha
Trenching +smoothing	T-130	Ripper+disk	80.000 Ft/ha
Uprooting	T-130	Root rake	35.000 Ft/ha
Soil crumbling	T-150	Disk	10.000 Ft/ha
Planting cuttings	MTZ 820.4	BDÜ-2E	50.000 Ft/ha
Care	MTZ 820.4	Slash chopper	10.000 Ft/ha
<b>Total</b>			<b>493.000 Ft/ha</b>

Table 4. Reforestation technology IV.

Reforestation (withh root ripping)			
Work phase	Power machine	Machinery	Specific costs
Site clearing	Front-end loader	VT-02	18.000 Ft/ha
Root ripping	T-150	Ripper wedge	45.000 Ft/ha
Care	MTZ 820.4	Slash chopper	10.000 Ft/ha
<b>Total</b>			<b>73.000 Ft/ha</b>

## 4. CONCLUSIONS

Based on the data it can be said, that by sowing, planting, and planting cuttings after the entire soil preparation, afforestation can be done at nearly similar costs, however the regeneration with root ripping means significantly less cost. However, this can't be applied to the extreme, because after a number of root ripping a high degree of degradation can be observed in the stand, as a result of which the assortment composition deteriorates and the tree utilization income decreases.

A well-founded opinion can therefore only be given by summing up the forest tending costs and the income of the extracted wood.

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## WATER FOOTPRINT: A NEW APPROACH FOR A MORE SUSTAINABLE FUTURE

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### ABSTRACT

Sustainability of water use has got into focus recently, as availability of fresh water resources is under depletion. Population growth, extreme weather conditions (drought), increasing global meat demand all results in higher water consumption of humanity and ecosystem. Water footprint is a promising indicator, which assesses both qualitative and quantitative deterioration of fresh water supplies. By identifying blue, green and grey water components, water use can be assessed in a more comprehensive way. Furthermore impact assessment of different components during production and processing let us identify crucial points of water use, where more efficient solution should be found. As a consequence of a more conscious and sustainable water use assessment considering water footprint, there is a chance, that future generations will inherit fresh water supplies at least in the same condition as we got it from our ancestors.

Keywords: water management, water footprint, blue water, green water, gray water

### 1. INTRODUCTION

Sustainability is a balance between economy, environment and society by approaching one segment e.g. agriculture considering all of its pillars or analysing that sector only based on each pillar (economic, environmental or social) separately. Two from sustainable development goals defined by UN (United Nations) in 2015 were related to water. Namely the sixth; Clean water and sanitation and the fourteenth; Life below water [31]. However these will be influenced by global trends in agriculture such as climate change. For increasing production capacity of crop production and animal husbandry, reasonable water use is crucial, especially if it is considered, that fresh water resource availability is under depletion. Higher average temperature, lower amount of precipitation, extreme weather conditions such as drought, flood or internal water all influence water availability and decrease water supply ability of natural ecosystems for humanity.

As it was highlighted above, dealing with water resources in a sustainable way is one of the biggest challenge in the 21st century. Water footprint is a comprehensive tool for understanding issues related to global water use and water consumption. However for finding the right solution, understanding definitions related to water footprint and analysing its components in appropriate way is inevitable and I hope this paper will help this process.

### 2. THEORY

#### 2.1. What is water footprint?

A new concept was developed to better understand the impact of water consumption by human activities, both direct and indirect, starting from the idea of virtual water trade [2] and Ecological footprint [37]. This concept is the Water Footprint (WF), introduced by Ref. [17], which is quantitative and qualitative

indicator. It is quantitative since it calculates the volume of water consumption to produce goods or services during their total supply chains, and it is qualitative since it assesses the amount of water required to assimilate pollutants based on the water quality standard in an ecosystem [8] [23] [24]. *'The water footprint is comprehensive indicator of freshwater resources appropriation, next to the traditional and restricted measure of water withdrawal. The water footprint of a product is the volume of freshwater used to produce the product, measured over the full supply chain. It is a multidimensional indicator, showing water consumption volumes by source and polluted volumes by type of pollution; all components of a total water footprint are specified geographically and temporally'* [16].

According to Ref. [4], the possible reduction of wasting water caused by production and consumption activities is a global issue considering water footprint. It refers to a quantitative amount of impact, however it also means a qualitative load according to the local water resource availability [12]. Research on water-energy-food nexus has become into focus recently [11]. The approach assesses the links between different aspects of the sustainability of food products and their impact on water resources. According to Ref. [34], *'water footprint (WF) is an indicator that accounts for both the direct (domestic water use) and indirect (water required to produce industrial and agricultural products) water use of a consumer or producer.'* The WF can be interpreted as an indicator of freshwater use that looks at both direct and indirect water use of a consumer or producer [30]. The WF of an individual, community or business is the total volume of freshwater that is used to produce the goods and services consumed by the individual or community or produced by the business. For being able to develop strategies for sustainable water use, green, blue and grey water footprint elements of WF indicator should be analysed in more details.

## 2.2. Blue, green and grey water

Water footprinting methods have been developed to account for green, blue, or grey water [25] [16], where the green water is defined as the rainfall that is held within the soil profile and used by the plants, and the blue water is defined as water used from groundwater and surface water resources. Blue water is made available to the plant via irrigation. The grey water is defined as the volume of water required to assimilate contaminants loads to the accepted (standard) levels in receiving water bodies [16]. Within the water footprint methods, both direct and in-direct water uses for a product or process are accounted for. The direct water use is defined as the water used directly in the production of a product, such as the green water from rainfall and the blue water from irrigation that is used to grow grass. Whereas in-direct water use is defined as the water used indirectly, such as in the manufacturing of fertiliser and production of the electricity that is used on the farm. Blue water is abstracted from rivers, lakes and groundwater. Agriculture accounts for approximately 85% of global blue water consumption [27]. Green water is used at the point where rain falls. According to Ref. [26], green water is the soil water held in the unsaturated zone, formed by precipitation and available to plants, while blue water refers to liquid water in rivers, lakes, wetlands and aquifers. Irrigated agriculture is based on blue water (from irrigation) and green water (from precipitation), while rainfed agriculture is based only on green water. Traditional water use statistics only take into account blue water. Conventional approaches to water management have focused on managing only the blue element of the water cycle. Ref. [19] did dairy specific interpretation of blue and green water by which blue water is the *'fresh surface water, groundwater and rainwater stored in artificial ponds'* and green water is *'water from precipitation that does not run-off or recharge the groundwater but is stored in the soil or temporarily stays on top of the soil or vegetation'*. In simply way blue water is abstracted from rivers lakes and groundwater and green water is used at the point where rain falls.

## 2.3. Blue, green and grey water footprint

Ref. [6] defined blue water footprint as blue water consumption from surface and groundwater resources through the total supply chain of a product. Consumption refers to water loss from groundwater body in catchment area by evaporation, returning to another catchment area or incorporation into a product. The green water footprint considers rainwater as green water resource, till it does not become run-off. The grey water footprint considers freshwater volume required to assimilate a certain pollutant load, which meet water quality standards of the region or country. There is more research on blue water resources as it has higher opportunity cost than green water and it is available in limited volume. However green water resources are scarce as well, especially if we consider that blue water can be substituted by green water in agriculture. Historical datasets only focused on blue water, thus green water as a factor influencing production has been under valued [10]. Ref. [10] and Ref. [35] started to emphasise the importance of green water in water management studies. The reason of this was that rainfed agriculture is the largest (green) water user worldwide. Irrigated agriculture is the largest blue water user worldwide. Therefore research started to assess the green component of the water cycle, e.g. Ref. [13] and Ref. [38].

Water footprint studies of European countries, such as Ref. [1], Ref. [28], Ref. [33], and countries outside Europe, such as Ref. [7], Ref. [21], and Ref. [36] all included both blue and green water in their water footprint assessment. The concept of grey water footprint expresses a pollution volume, thus can be compared with volume of water consumption [8]. Grey water footprint is interesting, if polluted water can be reused after different kinds of waste water treatments. If treated water reach the quality standards of irrigation water, it will decrease the negative impact of the system on the environment. Freshwater appropriation consists of both consumptive water use and the water required to assimilate pollution so all green, blue and grey water footprints [23]. Assessing grey water footprint has got into focus recently by analysing the importance of pollution as a driver of water scarcity. Ref. [29] revealed that water consumption is not the only factor causing water scarcity; pollution plays an important role as well. Taking into account grey water footprint, production could be more sustainable environmentally. If this treated grey water can substitute blue water for irrigation, the production might be more sustainable in an economic way as well.

## 3. WATER FOOTPRINT METHODOLOGIES

### 3.1. WFN-Water footprint Network

According to Ref. [14] most research on water footprint follow volumetric approach of the Water Footprint Network (WFN). Ref. [34] made a review on the WF indicator and its applicability for EU28 policy using this approach as well. They differentiated WF of production (WF<sub>prod</sub>) and the WF of consumption (WF<sub>cons</sub>) of a geographical region (EU28). WF of production is the sum of direct and indirect water use of domestic water resources. WF of consumption is the sum of direct and indirect water use of domestic and foreign water resources through domestic consumption. A balance between the two is reached by virtual water flows (import and export), which result from the trade in industrial and agricultural products.

EU28 is a net virtual water importer as it imports more virtual water than it exports. The WF of agricultural products is 91% of the total WF<sub>prod</sub> and 89% of the WF<sub>cons</sub>. This study also assessed geographical environmental sustainability indicators such as green and blue water scarcity and water pollution level. The blue water scarcity indicator is calculated by dividing the blue WF<sub>prod</sub> by hydrological water availability minus environmental flows in the geographical area. The green water scarcity indicator is calculated by



dividing the green WFprod by the green water availability of a geographical region. The water pollution level indicator is obtained by dividing the sum of all grey WFprod in a catchment to its actual runoff. The above mentioned indicators used by Ref. [34] certify that all blue, green and grey water components represent important roles in volumetric approach of the Water Footprint Network. Applying them let one better understand environmental sustainability of agricultural products. Ref. [4] interpreted WF regarding the water consumption of agricultural products from “cradle to gate” using also WFN database for the WF indicator as main reference. They provided a free dataset of the WF indicators available for agricultural products. This study revealed that sustainability of an agricultural product is closely related to its impact on water resource.

### 3.2. LCA: Life Cycle Analysis

The Life Cycle Analysis approach as developed by the LCA community (which includes the weighted WF approach [34]. Life Cycle Assessment is a ‘compilation and evaluation of the inputs, outputs and potential environmental impact of a product system throughout its life cycle’ [19]. LCA is relevant in comparing the environmental performance of a product during its entire production chain. Impact of water consumption and degradation are usually assessed within the framework of water footprint assessment. Ref. [19] interpreted three main levels of impact assessment adapted from Ref. [3]. Inventory consists of entering and exiting flows focusing on direct and indirect water sources water sources and uses in order to present where reductions can occur. Midpoint assessment illustrates indicators regarding degradation cause-effect chains. Endpoint assessment analyses specific indicators for potential damage to human health, ecosystem quality and resources. Besides ecosystems and human health, water serves as natural resource for several economic activities. Thus population growth and economic development results in increasing human freshwater use. However, at regional scale, main part of global freshwater withdrawal occurs in watersheds, which already experiencing high water scarcity. According to Ref. [25], *‘the humanity’s water footprint (referred as the sum of withdrawals multiplied by local water stress indices) must be globally reduced by approximately 50 % to achieve a sustainable water use.’* Thus assessing environmental aspects of freshwater use is inevitable. Diverse initiatives are available for developing and standardising analytical tools to measure and assess freshwater use at both regional and global scale. Furthermore these initiatives aim to improve freshwater resource management and the environmental performance of products and operations. According to Ref. [5] water scarcity considering domestic use could be influenced by shifting environmental burdens to other LC stages and impact categories. Withdrawn and released water can be associated with loss of functionality associated with water stress. Modelling approach of their study presented impact of diseases and malnutrition as years of life lost. The so called AWARE (available water remaining) method was based on the quantification of relative available water remaining per area, once the demand of humans and aquatic ecosystems has been met. Ref. [6] WULCA (Water Use in Life Cycle Assessment) consensus characterization model for water scarcity footprints: The WULCA consensus characterization model for water scarcity footprints: assessing impacts of water consumption based on available water remaining (AWARE). Water scarcity results when cumulative human impacts decrease water supply or quality to the point that water demand of humans and the environment cannot be satisfied [32]. Water scarcity is generally related to harsh climatic conditions, but is sometimes increased by low economic development that limits exploitation of groundwater resources or optimal management of available water. Understanding links between inventory analysis and impact assessment is crucial to get plausible conclusions regarding water footprint process. The reason of why it is assessed, the unit of assessment such as product, organisation, community or activity and system boundaries of investigated process all have to be clearly identified in order to get the goal and scope of definition (ISO 14046). During

inventory analysis, all water flows in and out of the operation need to be quantified by water source or destination.

### 3.3. Calculation of blue, green and grey water footprint of a process step

Basically water footprint of a process is expressed as water volume per unit of time. It can be expressed as water volume per product unit in case when it is distributed over the quantity of product that results from the process (product units per unit of time).

### 3.4. The blue water footprint in a process step

$$WF_{process\ blue} = Blue\ water_{Evaporation} + Blue\ water_{Incorporation} + Lost\ Return\ Flow \quad (1)$$

Unit: [volume/time]

The first component, blue water evaporation, is the most important one. All kind of evaporation is taken into account such as; the water that evaporates during water storage, transport, processing and collection or disposal. However other three components should be included when relevant. Blue water that is incorporated into the product, blue water that does not return to the same catchment area, for example, it is returned to another catchment area or the sea and blue water that does not return in the same period, for example, it is withdrawn in a scarce period and returned in a wet period. Thus the amount of available blue water consumed by humans, the groundwater and surface water flow that is left to sustain the ecosystems and water that is returned in another period of time are also considered.

### 3.5. The green water footprint in a process step

Calculating green water footprint in a process is relevant where the product is based on crops or wood, as it consumes rainwater by evapotranspiration, which then is incorporated into the harvested crop or wood.

$$WF_{process\ green} = Green\ water_{Evaporation} + Green\ water_{Incorporation} \quad (2)$$

Unit: [volume/time]

### 3.6. The grey water footprint in a process step

The grey water footprint is calculated by dividing the pollutant load ( $L$ , in mass/time) by the difference between the ambient water quality standard for that pollutant (the maximum acceptable concentration  $c_{max}$ , in mass/volume) and its natural concentration in the receiving water body ( $c_{nat}$ , in mass/volume). The natural concentration in a receiving water body occurs, if there were no human disturbances in the catchment thus  $c_{nat} = 0$ .

$$WF_{process\ grey} = \frac{L}{c_{max} - c_{nat}} \quad (3)$$

### 3.7 Point sources of water pollution

In the case of point sources of water pollution, when chemicals are directly released into a surface water body in the form of a wastewater disposal, the load can be estimated by measuring the effluent volume and the concentration of a chemical in the effluent.

$$WF_{process,green} = \frac{L}{c_{max} - c_{nat}} = \frac{Effl \cdot c_{effl} - Abstr \cdot c_{act}}{c_{max} - c_{nat}} \quad (4)$$

*L*: the pollutant load (mass/time)

*c<sub>max</sub>*: the maximum acceptable concentration of pollutant *c<sub>max</sub>*, in mass/volume

*c<sub>nat</sub>*: natural concentration in the receiving water body (*c<sub>nat</sub>*, in mass/volume)

*Effl*: the effluent volume (*Effl*, in volume/time)

*c<sub>effl</sub>*: the concentration of the pollutant in the effluent (*c<sub>effl</sub>*, in mass/volume)

*Abstr*: the water volume of the abstraction (*Abstr*, in volume/time)

*c<sub>act</sub>*: actual concentration of the intake water (*c<sub>act</sub>*, in mass/volume)

### 3.8 The total water footprint of a process

The total water footprint of the process of growing crops or trees (*WF<sub>proc</sub>*) is the sum of the green, blue and grey components:

$$WF_{process} = WF_{process,blue} + WF_{process,green} + WF_{process,gray} \quad (5)$$

*Unit*: [volume/mass]

## 4. CONCLUSIONS

Qualitative and quantitative deterioration of water resources as a result of human activity will become more serious, basically since the water is essential for both plant and animal sectors, and especially, due to climate change. Other factors such as social situation and habits, technological leakage, water price and tourism all have impact on resident's water consumption. According to Ref. [29], 'Even without negative climate change effects, the water consumption for food production will increase to meet demands of a 50% larger global population'. For producing much more food with high water requirement, applying sustainable water use management during its production and processing phase is crucial. Current water sources should be preserved for future generations at least in the same condition as it was inherited from ancestors. By understanding and applying water footprint indicator primary producers (farmers) and processors can assess water use of their activity. If they can calculate where are the points with the highest water demand during production and processing phase, they will be able to find solutions for more water efficient operation. Considering blue, green and grey water use separately let them analyse water use in a comprehensive way by which they can identify more precise consequences and recommendations.

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## COMPETITIVENESS OF SMALL ENTERPRISES IN THE ONLINE SPACE AMONG THE HUNGARIAN COMPANIES

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### ABSTRACT

There have been several studies about competitiveness and within this, company competitiveness. These studies include mainly the whole company spectrum in terms of company size from micro to large enterprises. There are studies which focus on large companies and the others on big and medium sized companies. There are studies which use mostly secondary data, and there is a few which use primary data. Although more studies do not take into consideration the fact that the operation mechanism and behaviour of small enterprises are different from the larger ones. Moreover, by using secondary data we are not able to look into the company, which does not ease the task of the researchers and business economics specialists. This is the reason for this study topic, which can fill a gap in the examination of enterprise competitiveness. In my analysis I focus on Hungarian small enterprises, and I do research using primary data. The research was done by a research team at University of Pécs Faculty of Business and Economics. I was also a member of this group, who analyses company competitiveness, but in my study I focused on the role of the companies in the online space. The online research of the companies was done with the co-operation of University of Pécs Faculty of Engineering and Information Technology, the result of which was integrated into the final sample. I deal with its descriptive analysis in this study.

Keywords: competitiveness, small enterprises, online presence, infocommunication

### 1. INTRODUCTION

The development of the Hungarian economy has been continuously a goal and now it is a goal too for the government. In the long-term economic development it is essential to keep the competitiveness in high level [7].

Of course the performance of a country can be described by many components, but among these the competitiveness indices can represent this status in a complex way. According to Ref. [4] in the past years Hungary was in 50. place in the world ranking list, in which there were some changes, but in 2018 Hungary reached better position, its result improved 5 positions, from 52. place to 47. place.

World Economic Forum found similar result, according to this Hungary was in 63. place, but in 2018 it improved 12 positions to 48. place in the competitiveness ranking [9] [10] [11].

It is obvious that there are differences between the score counting methods, but it can be declared that Hungary reached similar place, and the improvement in the ranking list refers to economic development.

In this economic development the companies get outlined role, and within this the small and medium-sized enterprises (SMEs). The productivity growth of the Hungarian companies and the strengthening of competitiveness get high priority from leading economic decision makers [5].

Thus this is apparent that this topic is relevant due to the above reasons and it is worth dealing with the role of the small enterprises in the economic development.

## 2. INTRODUCTION OF METHODOLOGY

In the past many studies dealt with company competitiveness. These show miscellaneous view in terms of company size. There are studies which examined the companies miscellaneously or focused on large company sector [1] [2] [3] [6]. Ref. [8] dealt with the competitiveness micro-level analysis of small enterprises, which examined especially the micro, small and medium-sized enterprises (SMEs). I analysed the competitiveness of the small enterprises along the research logic of this model.

Before going on, it is useful to determine what do we think of company competitiveness: *“The competitiveness of small enterprises is the close relation of the human capital, financing, co-operation, offered goods, administrative routines, competitive strategy, used technology, marketing, internalization and online presence. These inner competences form a system, which enables to compete efficiently with other companies and to produce goods/services which are valued highly by the customers”* [8]. It can be seen that the competitiveness of the small enterprises is a complex conception. In the final sample there were almost 800 companies, which are representatively layered in terms of company size, branch of industry and region. These companies were analysed according to a specific approach, the conceptual model of which is described in Figure 1.



*Figure 1. The conceptual model of the competitiveness of the small enterprises [8]*

On the Fig. 1. it is visible that competitiveness is built from pillars (e.g. human capital, financing, co-operation etc.). In order to speak about high level competitiveness, all pillars should be strong, since the logic of the model is that the pillars should be on high level to reach a high level of company competitiveness. These pillars are built from so called variables. These variables were made to help the model structure, what was put in form of thematic questions in the used questionnaire. All in all, it can be stated that the competitiveness of small enterprises was created in a complex way, taking into consideration the different factors. Among these there are hierarchical order and it makes finally the SME index, what can describe the competitiveness of the small companies (Figure 2.).

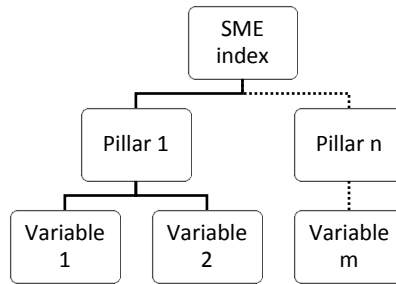


Figure 2. The hierarchical structure of the methodology of SME index [8]

The Fig. 2. has already shown the pillars of the model but I have not spoke about the variables yet. The introduction of these would be very long, this is the reason why I mention only some of these. The human capital pillar deals with human resource management, qualifications, incentive scheme. The co-operation represents types of co-operations, relations with external institutions, co-operation time etc. The complete description of the conceptual model was done by Ref. [8], this is the reason why I describe only the essence of it.

First of all, the creation and normalization of the variables and pillars were made.

$$x_{i,j} = \frac{z_{i,j}}{\max z_{i,j}} \tag{1}$$

where:

all  $j= 1 \dots 10$ , the number of the pillars

$x_{i,j}$  the normalized score value of the  $j$  pillar of the  $i$  company

$z_{i,j}$  the original pillar value of the  $j$  pillar of the  $i$  company

$\max z_{i,j}$  the maximum value of the  $j$  pillar

The average value of the pillars showed heterogeneous distribution, that is why it must have been equalized. For this the average of the average of the pillars was created:

$$\bar{x} = \frac{\sum_{i=1}^n x_i}{n} \tag{2}$$

In order to keep the values in [0,1] domain, the values were raised to the power of  $k$  and were weighted with themselves:

$$y_{i,j} = x_{i,j}^k \tag{3}$$

Then the value of  $k$  should have been determined in order to solve the following equation:

$$\sum_{i=1}^n x_{i,j}^k - n\bar{y}_j = 0 \tag{4}$$

Then it came the Penalty for Bottleneck principle. In this case the adjusted pillars were punished with the help of the so called penalty function according to the following:

$$h_{(i),j} = \min y_{(i),j} + (1 - e^{-(y_{(i),j} - \min y_{(i),j})}) \tag{5}$$

where

$h_{i,j}$  the modified value after the penalty in the case of the  $j$  pillar of the  $i$  company

$y_{i,j}$  normalized value in the case of the  $j$  pillar of the  $i$  company

$y_{\min}$  the minimum value of  $y_{i,j}$  in the case of the  $i$  company

$i = 1, 2, \dots, n$  = the number of the companies

$j = 1, 2, \dots, m$  = the number of the pillars

After the usage of the function the value of all pillars can be determined between 0 and 1, which shows which pillars are the weak points of the company. The higher this value is, the better. It is important to mention that disharmony between the pillars has negative impact on the competitiveness, and the weak pillars weaken the other pillars. Finally, the creation of the competitiveness score comes, which gives the SME index. This happens with the addition of the values of the 10 pillars. Then the results of the research will follow.

### 3. RESULTS OF THE RESEARCH

Previously it was mentioned that there were almost 800 companies in the final examined sample. Within this, the companies showed diverse picture but in this study I examined only those companies who are present somehow in the online space. As it was expected, not all the companies have online presence. This case it means 405 companies out of the 798 (51%). Classifying the companies as per the national economy sectors according to the factor that they are present in the online space, it can be stated that 10 companies (2,7%) operate in the agricultural sector, 95 companies (25,5%), in the industrial sector and 267 companies (71,8%) in the service sector. 33 companies did not give its main activity but is was a viewpoint only in the sector classification.

Classification based on the employed staff members shows that the micro enterprises (1-9 staff) takes the 48% of the examined sample, the small enterprises (10-49 staff) are present with 40%, and the middle sized companies (50-249 staff) have 12% share.

The age groups of the companies in the four categories are the following: there are 15 companies (3,7%) the age of which is between 1-3 years, 42 companies (10,4%) the age of which is between 4-7 years, 74 companies (18,3%) the age of which is between 8-12 years and finally 274 companies (67,7%) the age of which is elder than 13 years. From this point of view, it can be stated that the elder is the company the higher ratio they are present. This refers to a relative maturity.

I examined also what strengths and weaknesses the companies have in terms of human capital. Five categories were created based on college degree ratio. There have not been any staff with college degree in case of 66 companies (16,3%), the ratio of the staff with college degree was low at 78 companies (19,3%), the ratio is medium in case of 77 companies (19%), the ratio is high at 76 companies (18,8%) and the ratio is remarkably high of the staff with college degree in case of 108 companies (26,7%). From this point of view, it can be stated that there are less companies who do not have any staff with college degree. With the others the ratio is balanced except for the last category, where the ratio of the staff with college degree is remarkably high because the number of these companies is the highest.

For company internationalization the presence of foreign language speaking staff is essential. This factor was examined too and the result is the following. There is no foreign language speaking staff at 132 companies (32,6%) and there is foreign speaking staff at 273 companies (67,4%). The distribution of the foreign speaking staff is interesting. There are 57 companies (14,1%) who have one foreign speaking staff, 59 companies (14,6%) where the staff can speak two foreign languages, 84 companies (20,7%) where three or four languages are spoken and finally there are 73 companies (18%) who can use five or more foreign languages. Thus a third of the companies cannot speak any foreign languages, but a larger proportion can and the ratio is relatively high where more foreign languages are spoken.

I wanted to get answer to the question, what is the share of the foreign customers in the total customer portfolio. 274 companies (67,7%) do not have any overseas customer, while 131 companies (32,3%) have somekind of overseas customers. Among these, there are 65 companies (16%) where the share of the foreign customers is not more than 25%, 27 companies (6,7%) where this share is maximum 50%, 28 companies (6,9%) where this share is maximum 75% and there are 11 companies (2,7%) where the share of the foreign customers is more than 75%. Interesting notice is that with the companies who have online presence, the foreign language usage and overseas customers are in inverse ratio. Afterwards the examination of the competitiveness scores will follow. The Fig. 3. shows the case of those companies who have online presence.

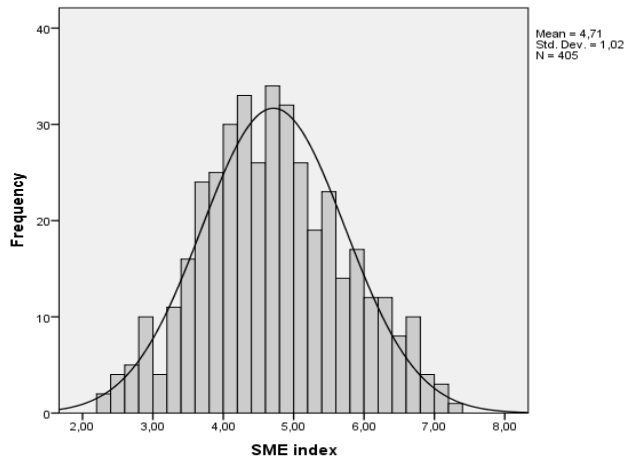


Figure 3. The distribution of competitiveness scores

From the histogram it can be read that there is symmetry with a smaller asymmetry. The average value of competitiveness scores of the companies with online presence is 4,71. It can be seen that there are little bit more companies who have lower scores this is the reason for the asymmetry. There are many companies between the scores of four and five. Then I examined the normal distribution curve of competitiveness scores, which is shown in Fig. 4.

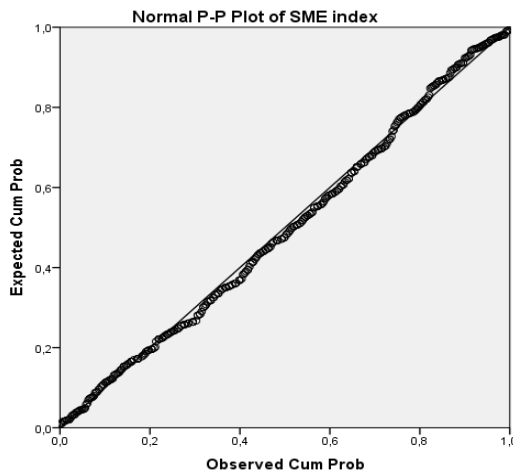


Figure 4. The normal distribution curve of competitiveness scores

A small right side asymmetry can be seen on the curve, but all in all it fits well to the normal distribution linear.

Of course all pillar values affect the competitiveness scores, although if the focus is on the online presence, the results can be seen on Fig. 5.

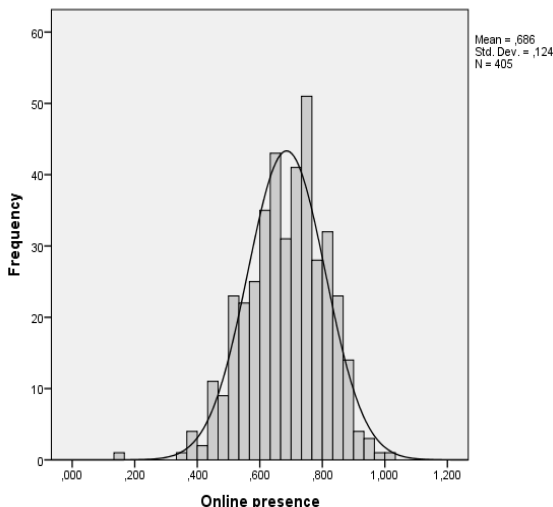


Figure 5. The distribution of online presence pillar values

The average value is 0,686 which is a higher value even if it is an average value, but if I examine the histogram more accurately, it can be seen that the results thicken between the scores of 0,7 and 0,8. This is similar to the preconception that the companies with online presence use more sophisticated online solutions during their operations.

#### 4. SUMMARY AND CONCLUSION

In my study I drew the attention to the conception that the increase of the competitiveness of the companies can be an efficient means of economic development. However, it is not useful to generalize and it is worth thinking separately of the companies. Since there are many small enterprises a good way can be to develop the competitiveness of the small enterprises, but only if the volume is the goal this will not be enough. For this there should be qualitative development within the company. For this a good means can be the Szerb's conceptual model, the mathematical logic of which has been introduced.

From the research it turned out that around the half of the Hungarian companies are not present in the online space. Examining their economy sector operations, a little bit less than three quarters of those companies who have online presence operate in the service sector, a quarter of them in the industrial and only a few operate in the agricultural sector. In the point of view of employment, a large proportion of them are micro and small enterprises and there are a fewest from middle sized companies. Regarding their age, they have been operating for a longer time and there are relatively few younger companies among them. The company staff have relatively high qualification, and more than two thirds of them have staff who can speak at least one foreign language. It is remarkable that the human capital potential is high among these companies, but it is fact that they have no or only a few overseas customers, which means that they do not use this potential well.

Since the SME index is based on 10 pillars, all pillars influence the final value. Since the model is so complex there was no opportunity to show all of them, but it is visible that the distribution of the values is



relatively symmetric and gives values around the average. But by examining the online presence pillar more closely, it can be found out that the values are high and outstanding.

Finally, it can be stated that the Hungarian companies should develop their attitude to be present in the online space. Those who are present in the online space, can use this ability, but it is not a cure-all itself because in one hand they should use the potential of the other fields well and in other hand they should improve its weak points. Taking into consideration of these points can help the development of the competitiveness of the small enterprises.

## ACKNOWLEDGEMENTS

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## COMPARATIVE STUDY ON THE IMPROVEMENT OF THE GAS EXCHANGE PROCESS OF A HIGH SPEED IC ENGINE USING SWINGING VALVE

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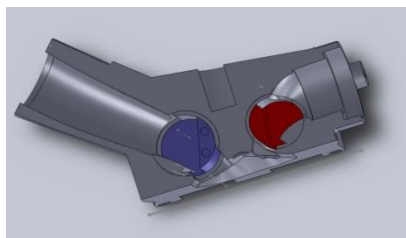
### ABSTRACT

Using poppet valves to control the air-fuel mixture entering and leaving the combustion chamber of an engine is just one among many other more flow efficient alternative solution. The geometry of the poppet valve and its valve seat are the main causes of the flow restriction in the internal combustion engines. The engine downsizing concept dictates to obtain more power from a given engine volume, therefore proportionally more air should be drawn into the cylinders to burn more fuel. These criteria best fulfilled with a new Swinging Valve (SwV) solution that enables the unhindered flow of air and exhaust gas through an engine's cylinder. The filling of a cylinder is improved while the pumping losses are decreased. In this experiment, a Super Flow SF600 flow bench was used to examine a Suzuki SV650 motorcycle engine's normal poppet valve cylinder head and a Swinging Valve cylinder head was constructed as well. First the flow parameters of the original cylinder head were obtained then the Swinging Valve head was investigated in the same way. The outcomes of the tests show the superiority of the new concept. The results will also be the base of further OD/1D engine simulations.

Keywords: IC engine, swinging valve, poppet valve, flow test, OD/1D engine simulation

### 1. INTRODUCTION

From the beginning of the earliest times of four stroke internal combustion engines, many ways of controlling air and exhaust flows were experimented. From these poppet valves came out as the most widely used solution. A very handy feature of them is that the gas pressure on the compression and expansion stroke increases the valve seating pressure thus improving sealing. To be able to do so the valve head has to be arranged in its port to practically block the way of gases. This characteristic is quite unwelcome because when the valve is opened the valve head is still located in the middle of the gas stream forcing the flow to change direction and decreasing the engine's breathing ability and effectively reducing its power capability. Another problem with the universally used poppet valve systems is their control method. The opening of the valve is done by a cam and lifting mechanism (tappets, rockers, etc.) while its retention to its seat is usually performed by a spring. The spring with the mass moving together with the valve creates an oscillating system that will resonate at certain engine speeds. This causes the valves to lose contact with the control mechanism and float. If the speed of the piston reaching TDC is sufficiently high the floating valve can smash into it. Another way of destruction is when the valve smashes into its own seat without the control of the cam/lifter. The result is overly high local stress and premature wear or breaking of the components. With the employment of Swinging Valves (Fig 1.) these boundaries of engine downsizing in general can be done more efficiently and environmental problems could be solved cheaper.



*Figure 1. Swinging Valve cylinder head section view*

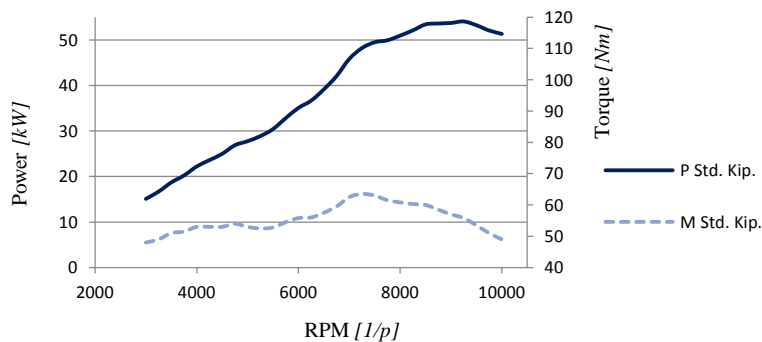
## 2. MATERIALS AND METHODS

### 2.1. Suzuki SV650

To find a suitable engine for the Swinging Valve project a Suzuki SV650 motorcycle engine had been chosen to validate the results. The reason of the choice was its availability; and the fact that it has separate cylinder heads that made actual manual work easier. Also this power-plant is a very robust design. If the Swinging Valve concept can be made working on this type of engine it would probably withstand the abuse in other designs as well Table 1 shows the engine specifications for the SV650 engine and Fig. 2. the torque and power curves as measured on a SuperFlow CycleDyn dynamometer.

*Table 1. Technical specifications of the tested engine and cylinder head*

Engine Make and type:	Suzuki SV 650	
Engine configuration:	V2	
Year of Manufacture:	2003	
Bore:	81 mm	
Stroke	62,6 mm	
Swept volume:	0,645 litres	
Valve stem diameter	4,5 mm	
Valve head diameter	Intake: 31 mm	Exhaust: 25,5 mm
Valve seat inner diameter:	Intake: 28 mm	Exhaust: 23,5 mm



*Figure 2. Torque and power curves of the Suzuki SV650 test engine as measured on a SuperFlow CycleDyn dynamometer*

### 2.2. Superflow SF600 flow bench

To examine the given cylinder head's flow capability at different valve lifts a SuperFlow SF600 steady state flow test bench was used (Fig. 3.), which is designed to measure the air-flow resistance of the intake and exhaust conduits of internal combustion engines. The actual test conditions can be found in Table 2., while specifications of the SF600 flow bench is in Table 3. In the case of intake testing it means the air flow resistance of valves, valve seats, manifolds, velocity stacks, and if applicable, restrictor plates. During the test, air is drawn through the cylinder head which is attached to the flow bench via an adapter that replicates the flow masking effects of the cylinder wall. The necessary pressure difference to perform the test is created by specially designed fans that are driven by a set of electric motors. The pressure drop across the valve/valve seat opening is kept constant at each valve lift points in comparison to ambient air

pressure and is observed on a vertical U-tube manometer (Fig 4.). Further along the air passage there are calibrated measuring orifices. Another U-Tube manometer is located on the machine and it measures the pressure drop across the actual open orifices. The scaling is in percentage of flow. For better accuracy and visibility the readout section of the manometer is inclined. The percentage value indicated on the inclined manometer is used together with a chart attached to the flow bench. The LCD display indicates flow values in cubic feet per second.



*Table 2 Information on the volumetric flow test of the SV650 cylinder-cylinder head assembly*

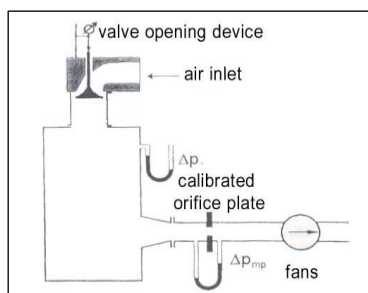
Date and place of test	18th February 2019, Szentes
Test pressure drop across valves	62,27 mbar (25 inches of water)
Ambient temperature	18°C
Relative humidity	49%
Barometric pressure	1014 mbar
Pressure ratio	1,0653

*Table 3 Specifications of Superflow SF-600 FC Flowbench*

Calibration Test Pressure:	62,27 mbar (25 inches of water)
Test Flow Range:	0 – 0,28 m <sup>3</sup> /s (0-600 CFM)
Capacity:	0,28 m <sup>3</sup> /s at 62,27 mbar pressure drop (600 CFM @ 25 inches of water)
Flow measurement accuracy:	± 0,5%
Repeatability:	± 0,25%
Test pressure accuracy:	± 0,127 mbar
Temperature measurement accuracy:	± 0,3 °C

## 2.3. Flow test methodology

For the actual test a specially designed valve opener device was used, which allows to open and close both valves independently. The valve opener had 1 mm pitch on the screw and was placed in line with the axis of the valve stem, each full turn meant 1 mm lift at the valve itself.



$\Delta p$ : pressure drop across the cylinder head  
 $\Delta p_{mp}$ : pressure drop across the orifice plate

Figure 4. Typical flow bench testing layout [1]

Regarding data to be processed, the general practice was followed and relative lift values were obtained in a dimensionless format, L/D:

$$L/D = \frac{L}{D} \quad (1)$$

where :

L: Actual valve lift [mm],

D: Valve diameter [mm].

This way direct comparison is made possible to other designs and makes.

According to [2] the valve was open to 0,3 x valve diameter which equalled approximately 1 mm. After turning the device on and adjusting the test pressure to the standard value (62,27 mbar/25 in H<sub>2</sub>O) the flow range was set to get at least a flow of 70%. That was indicated on the inclined manometer. During the test the flow range was adjusted as requested to keep the flow in the desired range. At each lift point the flow was recorded in cubic feet per second and then converted to ISO unit m<sup>3</sup>/s.

Leakage test:

Before the flow test the standard test depression was applied to the cylinder head while all the valves and openings were kept closed. To get repeatable results, it was necessary to take any leakage into account and deduct it from the actual results. According to flow bench manufacturer recommendation the amount of leakage flow could be accepted if it was between 0...10 Cubic Feet per Minute (CFM, 0...16,99 m<sup>3</sup>/h). During testing of the SV650 cylinder head the leakage was 1,4 CFM (2,379 m<sup>3</sup>/h) for the intake test and 1 CFM (1,699 m<sup>3</sup>/h) for the exhaust test so all the openings and flat surfaces of the tested assembly were acceptably sealed to the outside environment.

## 3. RESULTS AND DISCUSSIONS

As stated in [1] an intake system that is more efficient in terms of flow losses is favourable as the volumetric efficiency and specific fuel consumption is improved. With better flow characteristics the spread of torque and exhaust gas emissions are also improved. In the light of engine downsizing efforts this translates to smaller engines with the same characteristics and driver perception that a larger, heavier

engine would produce with higher fuel consumption. With the flow bench test the flow capabilities of these boundaries are established to the maximum valve lifts. The obtained volumetric flow data was plotted (Fig. 5.) and to allow further comparison with other engine data the Coefficient of Flow (Cf) for all valve lifts were calculated as well according to the test equipment's Operators Manual [2]. The cylinder head was tested without any attachment. To smooth out the flow over the edge of the intake tract modelling clay was used to streamline the entrance of the port and eliminate any detachment of flow downstream the intake entrance. After the measurements taken on the poppet valve cylinder head the newly designed Swinging Valve head was also tested with the same procedure as mentioned above. To get comparable results the flow measurements of the Swinging Valves were performed at the exact opening positions where the SwV flow areas exactly matched the flow areas of the poppet valves at their respective lift points. The results can be seen in graphical form below in Fig. 5.

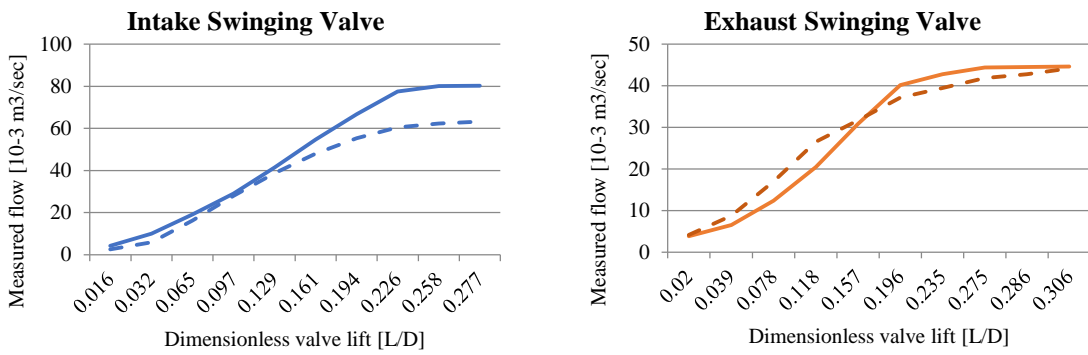


Figure 5. Graphical representations of measured flow parameters of the intake and exhaust Swinging Valves. For comparison, flow values of the original poppet valves are shown with dashed lines

From the measured data the Coefficient of Flow (Cof) was established at each lift point. The calculation was performed according to [2] where the Theoretical Volumetric Flow Rate (TVFR) through a unit area of a perfectly streamlined orifice is used as a datum in the calculations. The value of TVFR is equal to the speed of flow of incompressible, ideal gas but the unit used adapts to the requirement of evaluating the specific flow capabilities of IC engine valves. For the definition of TVFR the following formula is used:

$$TVFR = \frac{\dot{V}}{A_t} = \frac{A_t \sqrt{\frac{2\Delta p}{\rho}}}{A_t} \quad (2)$$

where:

$\dot{V}$ : Volumetric flow rate [ $m^3/s$ ],

$A_t$ : Flow area of test orifice [ $m^2$ ],

$\Delta p$ : pressure difference across the orifice [ $Pa$ ],

$\rho$ : Density of air [ $kg/m^3$ ].

Entering the values of standardized test pressure of 62,27 mbar and the density of air of 1,222  $kg/m^3$  the resulting Theoretical Volumetric Flow Rate is 100,95  $m^3/sm^2$  or  $m/s$ . Since this value is just reaching 0,3 Mach so air is considered to be an ideal, incompressible gas while the flow as adiabatic. This value is used as a datum for the calculation of Coefficient of Flow (Cf) of the intake and exhaust valves:

$$Cf = \frac{\dot{V}/A_{ac}}{TVFR} \quad (3)$$

where:

$A_{ac}$ : Actual valve flow area at each valve lift point, where the flow is perpendicular to an imaginary cylindrical flow surface [ $m^2$ ]

This type of definition is rather idealized because it assumes that flow across the valve is determined by valve diameter. Moreover the imaginary flow surface generated during valve event is cylindrical and particles travel through it perpendicularly (Fig. 6).

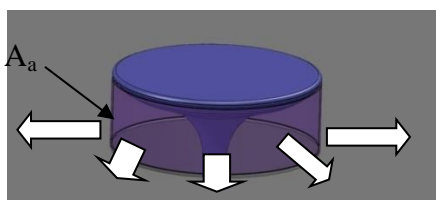


Figure 6. Imaginary flow area of a poppet valve. The white arrows show the assumed particle flow trajectories

After entering the actual values of valve lift points for the intake and exhaust valves the values of Coefficient of Flow were determined for each valve lift points. These are represented graphically in Fig. 7. From the graph it is clear that the exhaust valves and ports with their 44,4% Cf are far from their capacity. Also the waviness of the graph indicates irregularities in the flow field. The intake port is just the opposite in terms of flow quality: the graph is smooth without disturbances in the flow field and plateaus at 42,5% .It shows that the design reaches its limit within the available valve lift. Therefore any development should be focused on this area to improve the intake breathing characteristics because that would largely improve the engine’s fuel consumption and overall efficiency.

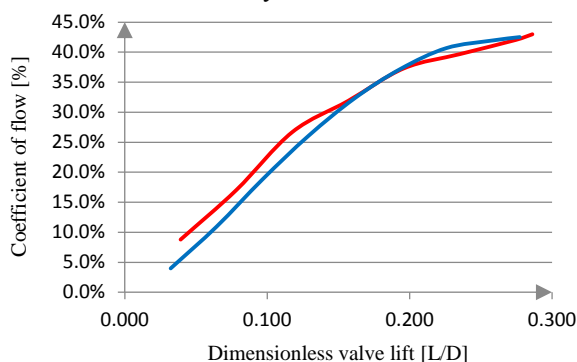


Figure 7. Calculated Coefficient of Flow for the intake (blue) and exhaust (red) poppet valves

The same procedure was repeated with the Swinging Valve cylinder head. The graphs of the calculated coefficient of flows show a marked increase in the flow capacity of the Swinging Valve cylinder head that can be seen in Fig. 8.



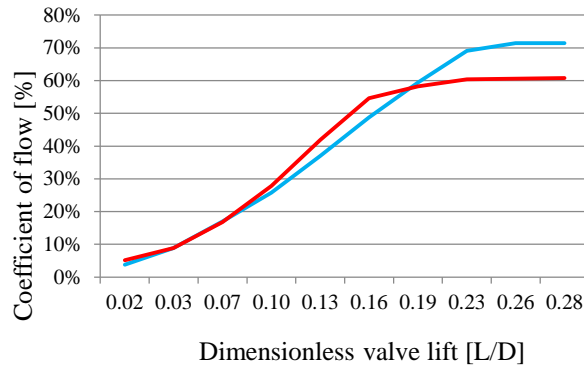


Figure 8. Calculated Coefficient of Flow for the intake (blue) and exhaust (red) Swinging Valves

To ease numerical comparison from the obtained data the area based average values of Coefficient of Flow were determined. For the poppet valve cylinder head the average value of CoF is 25,38% for the intake valves and 25,48% for the exhaust valves. The same parameters for the SwV cylinder head are 39,94% and 36,84% respectively which is 14,5% and 11,36% increase for the intake and exhaust valves respectively. To facilitate further research with OD/1D engine simulations Coefficient of Discharge (Cd) was also calculated, which is the actual rate of contraction of flow. In this case the flow area is conical and it changes during valve lift. This behaviour is embedded in the calculation procedure [3] (Fig 9.).

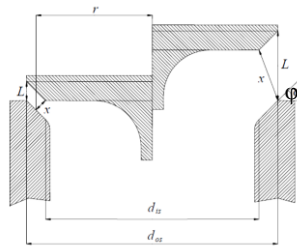


Figure 9. Graphical representation of the shape and position of the flow area [3]

For the calculation first the theoretical flow area ( $A_t$ ) must be determined. The surface area of a cone frustum is given by:

$$A_t = X\pi \left( \frac{d_{\max} + d_{\min}}{2} \right) \quad (5)$$

where:

$d_{\max}$ : Greater diameter of the cone frustum [m],

$d_{\min}$ : Smaller diameter of the cone frustum [m],

X: Side wall height of the cone frustum [m].

If the lift is sufficiently small then the value X is perpendicular to the valve seat. As the valve lifts ever higher, the value of X is such that the wall of the frustum is no longer perpendicular to the valve seat (Fig. 7). The limiting value of lift when this occurs is given by the following equation:

$$L_{\lim} = \left( \frac{d_{os} + d_{is}}{\sin 2\varphi} \right) \quad (6)$$

Up until the valve lift is equal to the limiting lift, the minimum flow area is the frustum cone area, such that:

$$A_t = X\pi \left( \frac{d_{is}}{2} + r \right) \quad (7)$$

Up to the limiting lift point X can be calculated using the following formulae:

$$X = L\cos\varphi \quad (8)$$

The value of r can be found:

$$r = \frac{d_{is}}{2} + X\sin\varphi \quad (9)$$

At lifts greater than the limiting value, the value of X is given by:

$$X = \sqrt{\left( L - \frac{d_{os} + d_{is}}{2} \tan\varphi \right)^2 + \left( \frac{d_{os} + d_{is}}{2} \right)^2} \quad (10)$$

Using these relations between valve and valve seat and from the above definition, Cd can be determined as follows:

$$Cd = \frac{A_{ac}}{A_t} \quad (11)$$

where:

$A_{ac}$ : Actual conical valve flow area at each valve lift point [ $m^2$ ],

$A_t$ : Theoretical valve flow area at each valve lift point [ $m^2$ ].

Since the experiment was a steady state flow test and the pressure drop across the valve annulus was kept constant at all opening point the flow speed was constant as well regardless of valve lift. For this reason the measured flow values collected during the test were determined only by the actual flow area. Dividing the volumetric flow rate values by the flow speed we obtain the actual flow area [4]. Using this theory the Coefficient of Discharge is calculated as follows:

$$Cd = \frac{\dot{V}_{ac}}{A_t \sqrt{\frac{2\Delta p}{\rho}}} \quad (12)$$

After completing the calculations the following graphs were plotted for the Cd values of the poppet valve cylinder head (Fig. 10.).

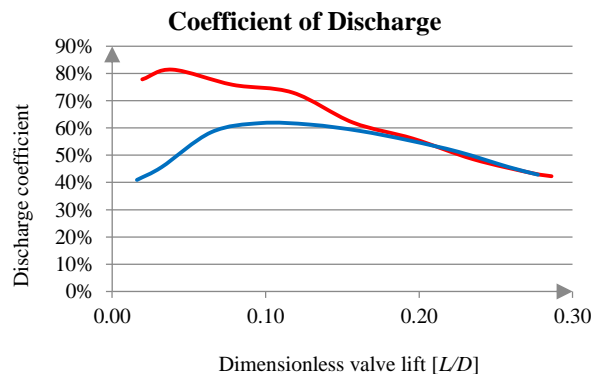
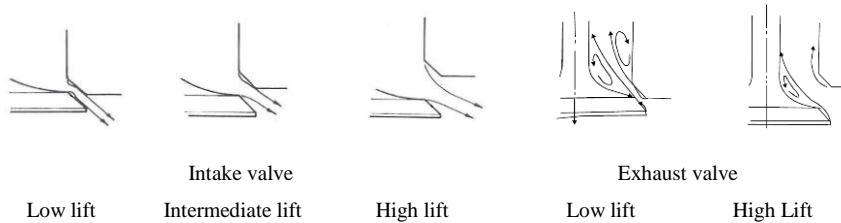


Figure 10. Coefficient of Discharge (Cd) values for Suzuki SV650 exhaust (red) and intake (blue) poppet valves

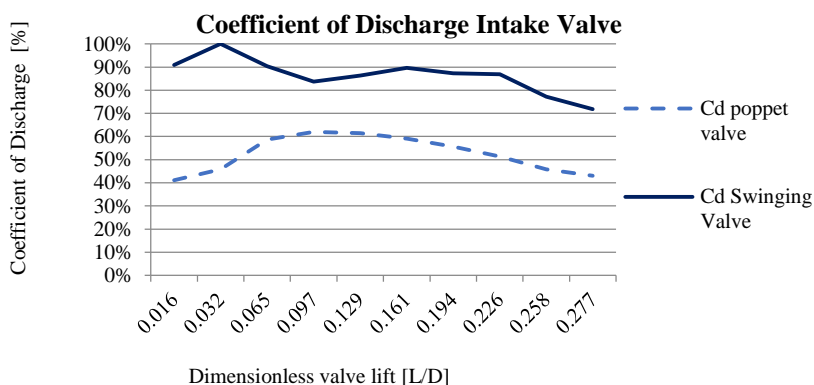
Even though the parameters remained unchanged during the test the flow changes throughout the valve lift range because the shape of the actual flow passage changes. In [5] is stated that there are three stages of the port opening where the incoming charge has different flow conditions (Fig. 11.). These are:

- Low lift: the main restriction is caused by the vortices at the edge of the intake valve sealing area and the inner diameter of the valve seat.
- Intermediate lift: The flow separates from the edges of the valve. The effective flow area is decreased due to the separated flow.
- High lift: The flow separates from the valve seat edge as well and the effective flow area further decreased but it is compensated by the increasing opening of the valve.



**Figure 11.** Three different stages of intake valve lift and the two phases of exhaust valve lift. Note how heavily affects the lift the actual flow patterns through the different phases [5]

As can be seen from the graphs above, the intake valves reached Cd value 61,8% highest because eddies generated by the edge of the valve seating rim and inner edge of the valve seat effectively limit the achievable Cd values. The exhaust valves behave differently since the flow direction is reversed (Fig 11.). Air moves through the moderately streamlined flow passage that is composed of the cylinder head surface and valve seat from one side and the valve greater diameter and edge on the other side. At very low lifts these two surfaces create a Venturi-like channel therefore the highest Cd value of 81,4% is reached at 0,039 L/D. As the valve lifts farther away from its seat the flow detaches from the surfaces and from about half of the useful valve lift the exhaust side performs similarly to the intake. For comparison, the Swinging Valve cylinder head Cd values were also plotted and were overlaid on the graphs of the poppet valve cylinder head (Fig. 12-13.). It is clear that the Swinging Valve arrangement generates better Cd values than the original poppet valve.



**Figure 12.** Coefficient of Discharge (Cd) values for intake Swinging Valve. For comparison, Cd values of the original poppet valves are shown with dashed lines

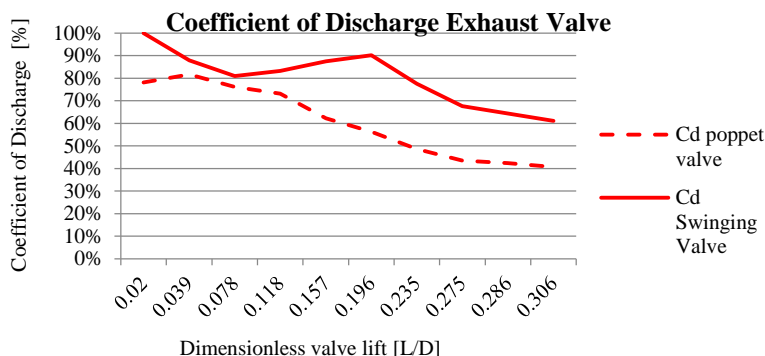


Figure 13. Coefficient of Discharge (Cd) values for exhaust Swinging Valve. For comparison, Cd values of the original poppet

## 4. CONCLUSIONS

The collected data shows that the traditional poppet valves heavily constraint any engine’s breathing ability. It is stated in [2] that the flow capabilities of an engine’s cylinder head closely correlate its performance and efficiency parameters. Also through empirical assumptions some other engine data can be derived from the flow numbers (eg. valve opening and closing points, power/torque values, etc.). As can be seen from the previous chapters a more efficient engine can be produced from the existing SV 650 with the unconventional Swinging Valve systems which present greater scope. This research program proved that an arrangement where the intake and exhaust ports are uncovered by a fully or partially rotating assembly can perform vastly better than the original poppet valve system. This special solution will eliminate the problems associated with poppet valves. The Cd values collected during this present work will be used for validation of CFD simulations and 1D engine models of poppet valve and engines with unconventional valve systems.

## ACKNOWLEDGEMENTS

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## EXAMINATION OF DON-TOXIN CONTENT OF MILLING BYPRODUCT GENERATED AFTER COLOR SORTING

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### ABSTRACT

Thanks to the favorable impact of vintage effect occurring in recent years the *Fusarium* contamination of wheat and consequently a high DON-toxin concentration is often caused problem. The DON-toxin in terms of human and animal health is a serious food safety risk factor. Therefore, it is important that there are methods during the wheat milling process which reduces the level of toxin. We confirmed in our earlier examinations, that with the help of modern color sorting machine the DON-toxin content of wheat items is effectively can be reduced. The question is, during the process how parallel changes the mycotoxin content of by-products, which are used primarily as animal forage. The authors are presented an analysis of these relevant experimental data. The results show, that the toxin content of the by-product is exceeds the starting wheat item's toxin content. However, the result of the regression analysis shows that no correlation in the toxin contents between the starting raw material, purified wheat and by-product. This should be considered to the users when they would like to utilize the by-product as ingredient of forage or feedstuff.

Keywords: DON-toxin, wheat, by-product, color sorting

### 1. INTRODUCTION

The production of safe products, that is the guarantee of food safety is primarily important in the entire system of food chain both during the production of foods and forages. It is important to assess the risk of the technology and to maintain it proficiently. This is supported by food safety laws and standards.

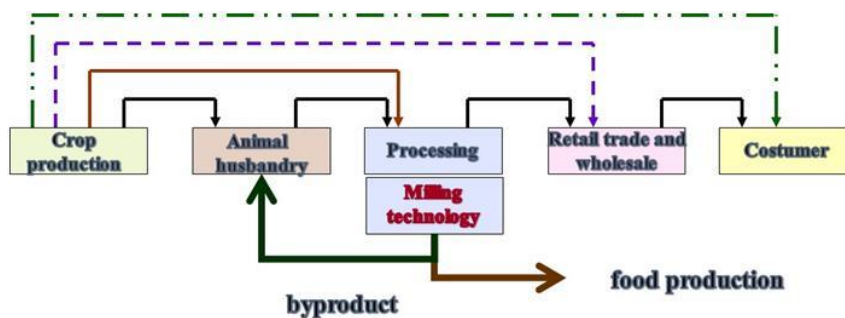


Figure 1. The return of milling by-products into the food chain

The goal of milling technology is direct food production. That is flour production from appropriate quality wheat which flour is basic material for pasta, bread and numerous essential foods. During the processing by-product is produced also, which primarily is used for animal forage. (Figure 1.)

This means, even if in an indirect way, these materials will get in touch with human body. That is the determination of the risks of by-product production and the development of treatment options is equally important as in the flour production. Producers particularly have to keep in mind this, when they perform developments or changes in the technological process. It is not enough just to concentrate on main

processes, but parallel the effect on by-product process must be analyzed also. Even in this case the requirements of legislation, and food safety regulation must be kept.

According to the above line of thought, there are two aspects of our research work when we investigate the reduction possibilities of DON-toxin content of milling wheat after harvesting. The primary goal is to investigate, whether usage of modern equipments in the production process has significant, and reliable effect on the reduction of mycotoxin content of wheat. Our experimental results proved the toxin level reliably can be decreased by application of adequate sorting and surface cleaner machines [13], [14]. But the question arises: This case how changes the toxin content of by-product, which primarily is used as forage. This is second aspect of research. We present the relevant data in this article. The topic is deliberately current issue, since in the last years several places intense *Fusarium* infection was experienced in the harvested wheat, which can cause high DON-toxin contamination.

Mycotoxins occur in the foods are secondary metabolic products produced by mould fungi. These have strong toxin effect, therefore they represent high risk in food safety respect [2], [11]. They can cause serious complications in human and animal bodies, illness which take shape shorter or longer period, and in many cases permanent damage [7], [10]. In cereals *Fusarium* ssp. is the most frequently occurring fungus. Compared with the most significant toxin producing fungi - like *Aspergillus*, *Penicillium* genera - *Fusarium* species are on the first place, because they produce one-third of the mycotoxins [11].

*Fusarium* species are parasitic organisms on many cultivated plants, but they cause the biggest damage on cereals [8]. The fungi infect cereals during the plant cultivation period in the field. Growing of fungi and formation of toxin may continue after harvesting also, if the cereals intended for food and the fodder industry are not handled properly [3].

The infection can cause significant economic damage in plant cultivation and animal husbandry equally. Getting into food chain the human health consequences may be considerable [4], [12]. Frequently occurring representative of fusariotoxins is the deoxinivalenol, or vomitoxin, more commonly known as DON-toxin. In reference [4] opinion this toxin occurs most frequently in wheat. Since this mycotoxin might be present both in cereals and cereal products it has great importance from food safety aspect.

The weather factors play a key role in appearance of toxin infection and in the development of toxin content of cereals [15]. The rainy, humid weather is favourable for fungi infection. However the effect of unfavourable ecological conditions can be decreased by application of preventive agrotechnical procedures [6]. According to the experiences the rainy weather results higher toxin level in the period of blooming and harvesting of wheat.

The size and the characteristic of *Fusarium* infection depends on which phenological phases was attacked the wheat by the fungi, that is the environmental conditions in which phenological phases are good for multiplication of fungi. This determines whether the seed-coat or the endosperm was effected by fungi infection. The color and the specific gravity of grain depends on the characteristic of infection. The difference of color and the specific weight determines the opportunity of sorting grains with higher toxin content, that is which applicable methods should be chosen to reduce toxin content of wheat item.

The experimental results of Reference [5] clearly proved the processes described in the preceding paragraph. Beyond that he demonstrated by analyses of infected wheat items there is no close correlation between the infection of outer and inner part of grain, that is formation of infection caused by different factors. All of this demonstrates: conventional cleaning, sorting methods cannot decrease reliably and efficiently the toxin concentration of grain items, that requires application of modern equipments.

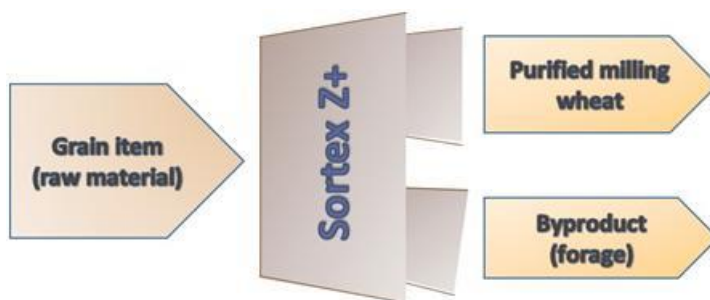
## 2. MATERIALS AND METHODS

During our research work we investigated, whether DON-toxin contamination can be decreased in the milling process by application adequate and modern machinery. It is primarily important to guarantee the toxin content of end-product flour remain below the legal allowable level in all circumstances. Beyond the legal requirements it is important also to keep the toxin level of basic foods as low as possible, reducing the intake of harmful substances into human body by foods.



*Figure 2. Sortex Z+ Optical Sorter*

Primary goal of our research work was to investigate whether achievable positive result by color sorting of grain items. To this we completed cleaning with Sortex Z+ color sorting machine (Figure 2.), then we measured the DON-toxin content of milling wheat samples before and after cleaning. But after cleaning of the milling wheat by-product is produced also, which is used as forage. (Figure 3.) That is this by-product return into the food chain too. (Figure 1.) It is shown from the process, that toxin content of milling wheat can be decreased by color sorting, but the mycotoxin content of by-product should be increased parallel. The question is: Is it possible to draw a conclusion about toxin concentration of by-product - used as forage - from the toxin content of starting raw material or purified milling wheat? That is the results of measures have done during the processing are suitable to decide whether the by-product is usable for forage production? To get answer we investigated the toxin concentration of wheat samples taken from three fraction and the results were evaluated statistically. Detailed description is in the chapter „Materials and methods”.



*Figure 3. Operational scheme Sortex Z+ color sorter*



The place of research was a mill, which has one of the most up-to-date technology in Hungary. We consider of importance to put the investigation into real production environments where the food safety technology and its operation can be studied directly. This type of investigation is not possible with model experiments. When we choose the place we looked for a mill where the experiments are achievable in controlled circumstances, complete mechanism of production process and its environment is transparent, trackable and measurable. Besides these the conditions and the experimental settings should be changeable and repeatable.

The basic material of experiment was durum wheat (*Triticum durum*). This species was chosen on the basis of the cultivation experience described in the literature. It was observed during the cultivation, that durum wheat is more sensitive to fusarium infection than other wheat species [1].

The characteristic of infection is widely influenced by vintage effect, as it was previously mentioned. Therefore the subject of investigation was the analysis of wheat items harvested in different years. In this article we summarized the evaluation results of samples of wheat items harvested in 2013 and 2014. The sampling system was elaborated according to the technological phases because of nonstop operation. The goal is to follow up the change of toxin content of wheat items during the production process. We formed three sampling place at the Sortex color sorting machine. First sample was taken directly before sorting. This indicated the initial toxin content of raw material. During the evaluation it was called 1. fraction. After cleaning there were two fractions. 2. fraction was the purified milling wheat, from which the flour is milled at the end of technological process. 3. fraction is the selected by-product which can be used as basic material for forage (Figure 3.). DON-toxin content of each fraction was measured and analyzed by statistical methods. Toxin concentration was determined AgraQuant Deoxynivalenol test kit, which operates with ELISA method and distributed by Romer Labs.

### 3. RESULTS AND DISCUSSION

So far the results clearly revealed the DON-toxin content of wheat items reducible by application of Sortex Z+ color sorting machine. The relevant analyses are described in detail in our previously published articles. This time we are looking for answer, whether there is correlation between toxin content of 3. fraction and toxin content of starting raw material (1. fraction) or cleaned wheat (2. fraction).

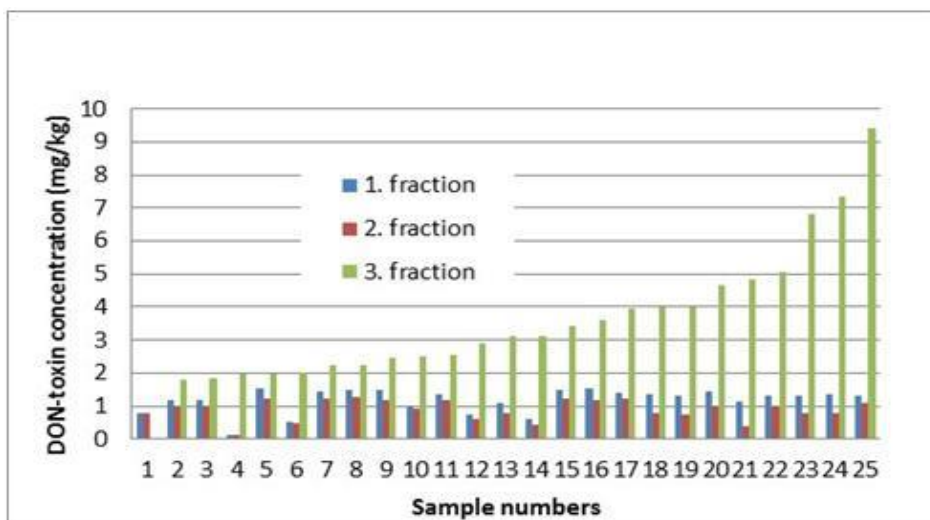


Figure 4. The DON-toxin content of generated fractions during the color sorting (2013.vintage)

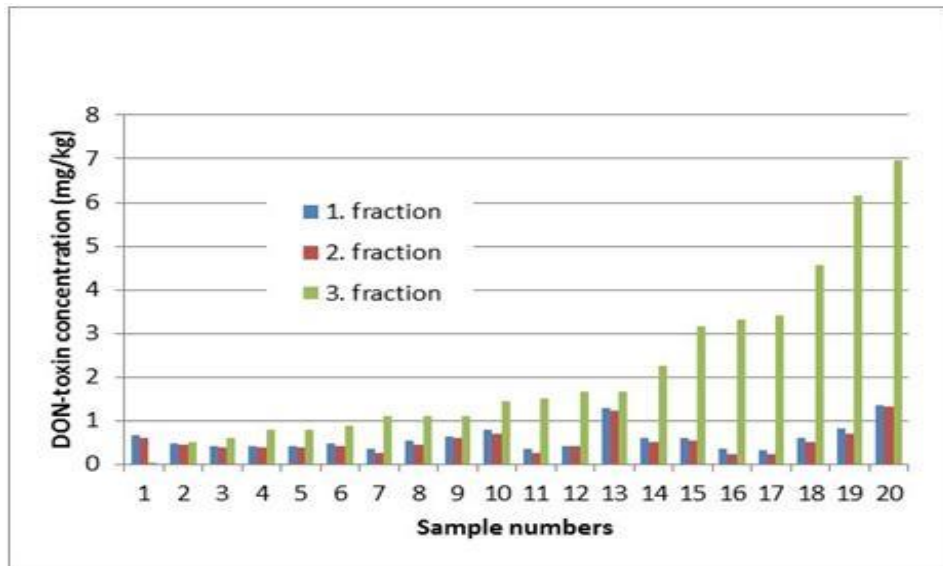


Figure 5. The DON-toxin content of generated fractions during the color sorting (2004. vintage)

Figure 4. and Figure 5. clearly show toxin content measured in 3. fraction is always higher than in the other two fractions.

To get answer to question raised in the first part of this chapter we arranged the samples ascending order according to DON-toxin content of 3. fraction in Figure 4. and 5. It is simply illustrated, if concentration of particular fractions has visible correlation with each other. The answer at first sight unambiguous „not“. Let pick up a data pair from the samples harvested in 2013 (Figure 4.) and a data pair from the samples harvested in 2014. (Figure 5.) and compare them. The results of comparison of samples 5. and 25. in the Figure 4. and the toxin content of samples 17. and 20. in the Figure 5. Our previous statement has been verified. There is no correlation between toxin content of three fractions neither in 2013 nor in 2014 harvested wheat items.

We used biostatistical methods to prove or reject our argumentation beyond any shadow of doubt. We completed detailed analysis by regression analysis. The correlation study can answer that question, if we can conclude the toxin content of by-product from initial DON-toxin concentration of wheat item or from DON-toxin content of cleaned wheat.

For the sake of filling the legal requirements we have to know the toxin contamination of starting raw material in order not to mill those wheat items which exceed the limit value. The simplest solution would be therefore to find statistical correlation between toxin concentration of starting raw material and the toxin concentration of by-product which can help to determine the contamination of by-product and to decide its further utilization. Thus first we did regression analysis referring to both vintage (Figure 6-7.).

According to Figure 6. (2013. vintage) the starting wheat item (fraction 1.) has 9 % effect on DON-toxin concentration of by-product (fraction 3.), nevertheless 91 % owing to the random effects. The Figure 7. shows, the initial toxin content of wheat had 24 % effect on toxin contamination of by-product. It can be said in both cases, there is no linear correlation between data pairs, so cannot be drawn conclusion to the toxin effect of by-product.

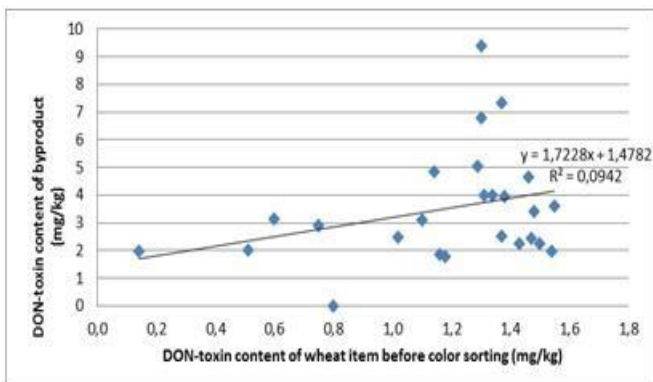


Figure 6. Correlation examination of the DON-toxin content between the wheat item before color selection (1. fraction) and milling by-product (3. fraction) (2013. vintage)

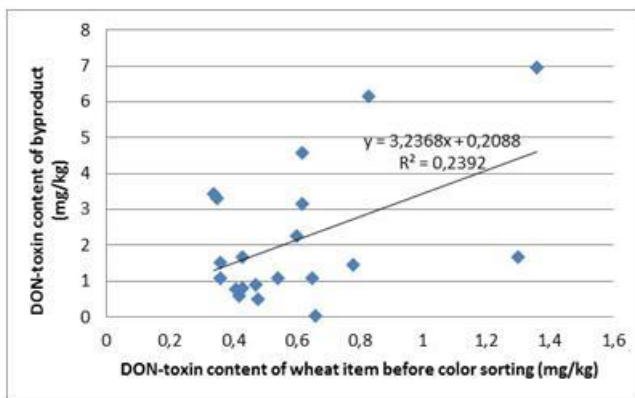


Figure 7. Correlation examination of the DON-toxin content between the wheat item before color selection (1. fraction) and milling by-product (3. fraction) (2014. vintage)

We investigated the correlation between 2. fraction (wheat after color sorting) and 3. fraction also. (Figure 8-9.).

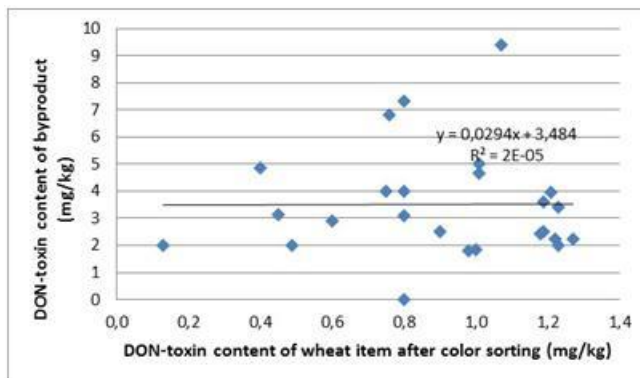


Figure 8. Correlation examination of the DON-toxin content between the wheat item after color selection (2. fraction) and milling by-product (3. fraction) (2013. vintage)

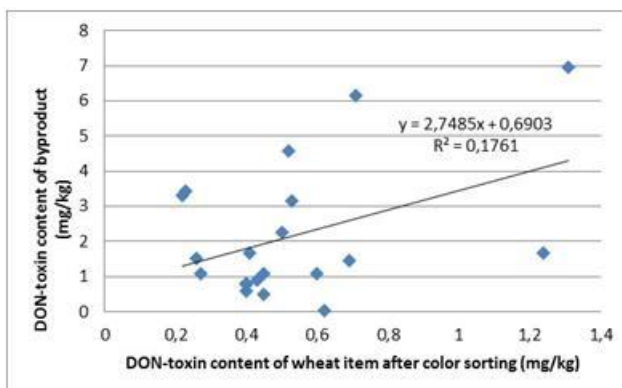


Figure 9. Correlation examination of the DON-toxin content between the wheat item after color selection (1. fraction) and milling by-product (3. fraction) (2014. vintage)

The result is similar to correlation examination of first and third fraction. Neither this case we found correlation between toxin concentration of sample pairs. We should highlight data of Figure 8., which display there is not at all correlation between toxin concentration of cleaned wheat and the toxin content of by-product. Thus these data will not give standing-point about quantity of harmful materials accumulated in the by-product.

It seems logical the rate of toxin reduction of 1. fraction should be the most effective factor on by-product. Although it is not simple to determine this in the production practice. To the determination of efficiency and respectively to make correlation analysis, we have to create a difference sample from data of 1. and 2. fraction. So we have to measure parallel the toxin content of 1. and 2. fraction also. The elements of difference sample are formed from the difference of data pairs of 1. and 2. fraction. The regression analysis also shows (Figure 10.-11.) there is no linear correlation between harmful materials of difference sample and by-product. Although the regression coefficient is higher than the results of previous correlation analysis were, but this does not mean close, function-like connection between two variables. From this we can draw the conclusion: DON-toxin content of by-product not only depends on efficiency of color sorting, but also other factors have role.

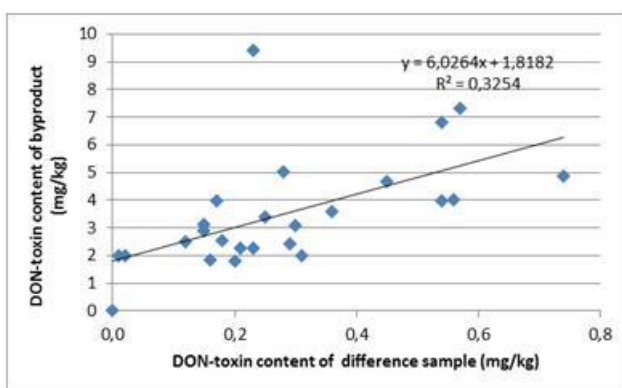


Figure 10. Correlation examination of the DON-toxin content between the difference sample (subtraction of 1. and 2. fraction) and the by-product (3. fraction) (2013. vintage)

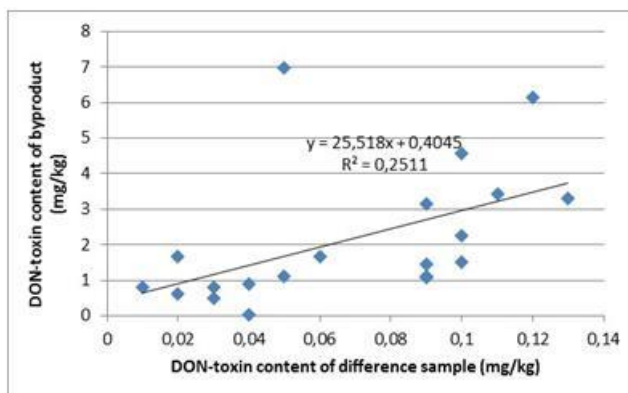


Figure 11. Correlation examination of the DON-toxin content between the difference sample (subtraction of 1. and 2. fraction) and the by-product (3. fraction) (2014. vintage)

## 4. CONCLUSIONS

From the results above we can come to the conclusion the color sorting of wheat intended for milling does not show close correlation neither with starting wheat nor with purified wheat toxin content (Figures 6-11.) That means it might occur we get by-product with high level harmful material after cleaning of wheat, which has low rate DON, and vice versa (Figures 4-5.). People who works in the milling industry should know this fact, because in many instances the cleaning by-product is sold as forage.

The color sorting that is the efficiency of cleaning does not show unambiguous correlation referring the toxin content of by-product. The reason of this can be explained by several factors. On the one hand the color sorting can select a high percentage of grains, which were infected in the early phase of blooming. A part of grains, which were infected in late phase of blooming do not show discoloration and they pass on process, because they are not selected. The rate of grains in a wheat item with different contamination character depends on vintage effect and agricultural technology applied during cultivation.

Toxin content of by-product is influenced by what kind of other components are selected and in which quantity by the color sorting machine. This determines the quantity of by-product and the rate of toxin contaminated grains within it. Besides the efficiency of preselection the vintage effect has role in determination of by-product. The vintage affects what kind of other infection attack the wheat, which might cause discoloration also. But the content of by-product depends on glassiness of grain, effectiveness of pre-cleaning and there are other deviations which besides the fusarium infected grains cause the selection from the milling wheat during color sorting.

Summing up we can say, if the mills intend to utilize the by-product as forage, they have to elaborate a test system which determine its DON-toxin content. The food safety requirements thus can be ensured under all circumstances, as well as the items with higher level toxin content than allowable level will not get into food chain.

There is a recommendation in the EU about the DON-toxin of forages. In the case of cereals and cereal products the recommended maximum limit value of toxin content by the EU is 8 mg/kg (2006/576/EC, [9]. In 2013. and 2014. vintage – which were not outstanding years from the point of fusarium infection of wheat – only one sample exceeded this limit. Thus if there is not possible to build up test system, the proper mixing rate is a way for the forage usage.

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## BANK SELECTION CRITERIA WHEN BORROWING A PERSONAL LOAN

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### ABSTRACT

In 2018 there was an increase in the number of people who borrowed personal loans, in both the European Union and Hungary. In Hungary, personal loans increased hugely by 48%. We conducted a non-representative survey. We wanted to determine those bank selection criteria that influence our decision on which particular bank we choose to borrow a personal loan. This information will help us to understand the customers better and let the banks provide a better service tailored to their needs.

Keywords: private loan, personal loan, bank selection criteria

### 1. INTRODUCTION

The personal loan is a type of private loan, which is a free credit, without provision, and usually it is short or medium-term [1].

The individuals can use the borrowed money for anything, like for buying a car, for buying durable goods or for a journey as well. The postulation of paying back the loan is that the person has to get his/her salary at bank account, because that will be the assurance of the refund.” [2]

We can experience the expansion of the retail lending in the eurozone and in Hungary as well. In the Eurozone the annual average credit growth at the individual sector at the end of 2017 was 3%, and in Hungary it is 2.7%. [3].

„Housing loans and personal loans continue to dominate the new disbursements. In 2018, the value of new contracts amounted to HUF 1,500 billion, corresponding to an increase of 37% compared to the previous year. In 2018 housing loans and personal loans accounted for 87 % of new loans, with an expansion of 31% and 48% compared to the volume in 2017.” [4]

Bátor researched the basic requirements, what we expect from bank’s financial services performance. „This requirements are the following: quality and convenience of service in the bank; friendly, helpful assistants; expert assistants; opportunity for personal customer service; wide spectrum for financial services; understandability and transparency of bank information materials; size of ATM networks.” [5]

Several important factors play a role in the decision making. Bátor and Sasné examined the importance of the sources of information during the bank selection process. They identified the following factors in order of importance: awareness of bank; professional opinions; expert opinion; opinions of acquaintances, family members; bank’s website; internet forums. [6]

In our research we examined the importance of bank selection criteria that influence borrowing personal loans, from the interest rates to the accessibility.

### 2. MATERIALS AND METHODS

We took a non-representative survey (electronic questionnaire), and we examined that which factors influence the individuals when they choose the bank where they would like to require loan. What impressed them in their decision, what are the reasons that affect these decisions. We have examined with a non-parametric test (Mann-Whitney U) the relationship between personal loan borrowing (borrowed personal loan previously or not) and bank selection criteria when borrowing a personal loan. We have used SPSS Statistics trial version.



### 3. RESULTS AND DISCUSSION

Mainly the 18-27 year old (39%) people filled in the questionnaire, but the 38-47 year old individuals (24%) also created a significant symmetric.

The survey was filled by women in 60.3%. In connection with the settlement type there is no remarkable differences, it is divided equally as the most people live in the county capital (36%) while in the smallest rate the villages were represented. (14.9%). (Figure 1)

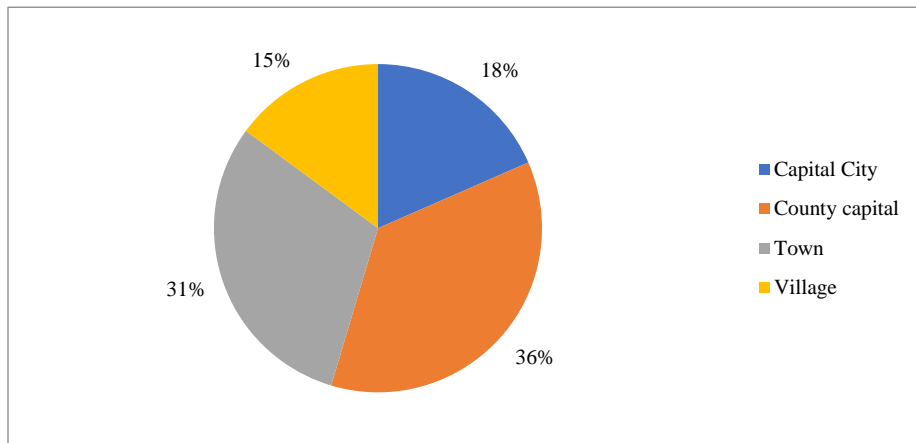


Figure 1. The settlement type of the respondents (our edit as the results of the research)

Considering the educational attainment mainly graduated people filled in the questionnaire (52% - higher education, 42% - secondary education ). 83% of the respondents were under HUF 250,000 income, 17% over HUF 250,000.

#### 3.1. Bank selection when borrowing a personal loan

On a one to sixth scala the individuals could mark how important the criteria when borrowing a personal loan for them (annual interest rate, fees, speed of requests). (1 means the least important factor, 6 means the most important factor.) As the result of the survey, we could establish the most important factors for the individuals. This factors are the following: annual interest rate (97%), other fees (93%), length of the credit analysis (91%), maximum amount of money to borrow (90%). The interest rate and the fees are the most important factors of the APRC that the banks must include in all of their conditions and advertisements. APRC says that annual how many percents do the individuals have to repay than they got.

Otherwise the people also considered the next factors important: preparedness of administrators (83%), speed of requests (79%) and accounting method the use of loan (75%). They didn't consider so important the maximum length of the term (67%) than the previous factors. The nearness of the bankbranch (58%), and the accessibility of the bankbranch (47%) aren't a major reason when they choose. The fact that somebody requires a loan at his bank and how getting to the bank didn't prove an important factor (50%). These results were ratified by the median and mode scores. (Figure 2)

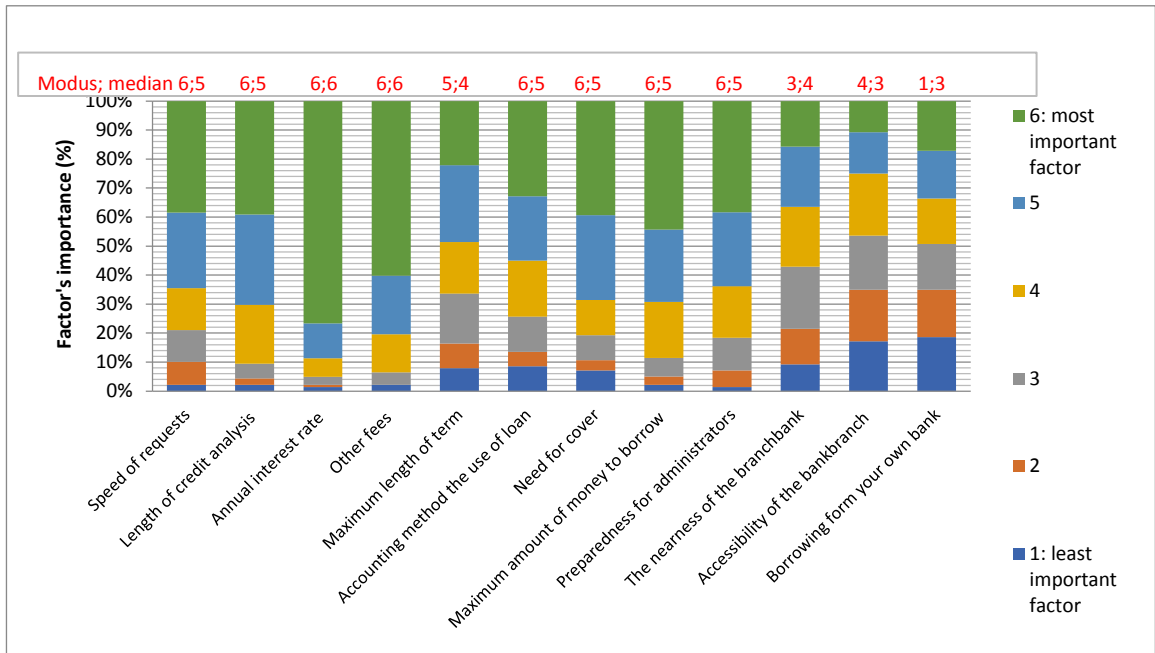


Figure 2. Bank selection criteria when borrowing a personal loan (our edit as the results of the research)

We have examined with a non-parametric test (Mann-Whitney U) the relationship between personal loan borrowing (borrowed personal loan previously or not) and bank selection criteria when borrowing a personal loan. We have used SPSS Statistics trial version (Table 1).

Table 1. Relationship between personal loan borrowing and bank selection criteria (our edit as the results of the research)

	Bank selection criteria	Significance level
Borrowed personal loan previously or not?	nearness of the branchbank	0.000
	accessibility of the bankbranch	0.000
	borrowing from your own bank	0.000

The results show that those who have borrowed a personal loan previously considered nearness and accessibility of the bankbranch, and choosing their own bank less important then those who have never borrowed a personal loan. The results of the non-parametric test were also supported by median and mode values (Table 2).

*Table 2. Significance level, median and modus values in the relationship between personal loan borrowing and bank selection criteria (our edit as the results of the research)*

	Borrowed personal loan previously or not?		Significance level (Mann-Whitney U)
	Yes	No	
The nearness of the branchbank			0.000
median	3	4	
mode	3	5	
The accomodation of the branch			0.000
median	3	4	
mode	1	4	
Borrowing at your own bank			0.000
median	2	4	
mode	2	6	

We have examined the relationship between bank selection criteria when borrowing a personal loan and the average monthly net income with a nonparametric test (Mann-Whitney U). On the basis of the results it can be stated that respondents with an income under HUF 250,000 ranked the accounting method for the use of loan and preparedness of administrators more important among the bank selection criteria than respondents with an income over HUF 250,000. The results of the non-parametric test were also supported by median and mode values (Table 3).

*Table 3. Relationship between average monthly net income and bank selection criteria (our edit as the results of the research)*

	Average monthly net income		Significance level (Mann-Whitney U)
	Under HUF 250,000	Over HUF 250,000	
Accounting method regarding the use of loan			0.016
median	5	4	
mode	6	1	
Preparedness of administrators			0.040
median	5	4	
mode	6	4	

In addition, we examined the relationship between bank selection criteria when borrowing a personal loan and level of education with a non-parametric test (Mann-Whitney U). The results show that respondents with secondary education ranked the length of the term and the accounting method for the use of loan more important than respondents with higher education. However, respondents with higher education assessed the accessibility of the bankbranch more important. The results of the non-parametric test were also supported by median and mode values (Table 4).

*Table 4. Relationship between education and bank selection criteria (our edit as the results of the research)*

	Level of education		Significance level (Mann-Whitney U)
	Secondary education	Higher education	
Maximum length of term			0.046
median	5	4	
mode	6	5	
Accounting method regarding the use of loan			0.011
median	5	4	
mode	6	6	
Accessibility of the bankbranch			0.038
median	3	4	
mode	2	4	

## 4. CONCLUSIONS

Based on our research, we suggest to banks that the interest rate as the most important factor should be as low as possible.

However, depending on the level of education and average monthly net income of the clients, and the fact whether they have previously borrowed a personal loan or not, other aspects may become important for certain groups, which should definitely be emphasized in banking communication.

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## QUALITATIVE STUDY OF PREFERENCES AND ATTITUDES TOWARDS HONEY CONSUMPTION IN HUNGARY

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### ABSTRACT

Honey is becoming increasingly popular among consumers for its health and nutritional benefits as well as several other functions. The survey identifies four main dimensions of honey-purchasing motivation: medical benefits of honey consumption, dietary quality, cosmetics and sweetener. There are very limited empirical analysis of the aspects of honey consumption. The present study contributes to fill this knowledge gap through a qualitative study of consumer perceptions, preferences and attitudes towards honey among Hungarian consumers through 86 in-depth interviews. The study identifies different consumer segments, which are also willing to pay premium prices for the Hungarian or local honey. Quality cues are defined by search attributes of the product (colour, taste, aroma, thickness), and ethical attributes (warranties, brand name, country-of-origin).

Keywords: honey consumption, consumer preferences, attitudes, qualitative study

### 1. INTRODUCTION

According to the Council Directive relating to honey of the European Union [1], „honey is the natural sweet substance produced by honey bees from the nectar of plants or from secretions of living parts of plants, which the bees collect, transform by combining with specific substances of their own, deposit, dehydrate, store and leave in the honey comb to ripen and mature.”

The chemical composition of honey is complex, containing approximately 181 substances including sugars, proteins, moisture, vitamins, minerals, 5-hydroxymethylfurfural (HMF), enzymes, flavonoids, phenolic acids and volatile compounds and must meet the compositional criteria laid down in the EU Council Directive relating to honey. The Directive also gives an exact definition of the types of honey products that can be sold under the given names and rules for labelling, presentation and information on origin [2]. Ref. [3] “Local Marketing of Honey” study described the honey market as a fragmented market, where the import and local producer honey compete.

Fresh, local honey is often (although not always) more highly valued than imported honey, and many beekeepers sell their product directly to consumers. The EU is one of the more viable honey producers in the globe, produce mixed flower honey in the highest volume.

The number of consumers following a healthy lifestyle has increased significantly in recent years, while the role of quality in the selection of products has increased [4], which is also reflected in conscious eating habits [5]. In addition to the growing demand for healthy food, the Hungarian National Beekeeping Association's actions to improve honey quality and the taking measures against honey counterfeiting also played a significant role in the increase in domestic honey consumption [6].

The image of consumers about honey has clearly improved. The interest in apiculture products has grown dynamically in recent years [7]. The consumption of honey is also increasing [8]. Annual honey consumption per capita rose from about 300 grams in 2010 to almost 800 grams by 2018 [9]. In addition, the range of beekeeping products is expanding year by year, with more and more high-quality honey made from special nectar. Experts predict a further increase in domestic honey demand, beside supply expansion. It is explained by the increasing awareness of consumers [10].

As acacia honey became a certified Hungarian speciality, it was associated with a high quality [11]. In Hungary the acacia honey is the variety of honey with the largest production and consumption [12]. There

are huge differences in quality between honey products, and consumers find difficult to differentiate the products [13] [14]. Ethical product characteristics, such as the origin of the product are also the focus of food consumption decisions [15].

In Hungary, the domestically produced honey is a suitable for an effective and successful marketing strategy [16] [17]. Since honey types differ from one country to another and in different regions in the same country due to floral origin, soil composition, season, environmental factors and treatment of beekeepers and other factors consequently, quality criteria differ from one honey type to another [18] [19]. Authentication of honey by its natural physicochemical properties, and other attributes is important to protect genuine unique quality honeys from fraud products and to create consumers trusts [20]. The survey of Ref. [21] identifies four main dimensions of honey-purchasing motivation: medical benefits of honey consumption, dietary quality, ethical character of honey and suitability with food consumption lifestyle.

## 2. MATERIALS AND METHODS

Our qualitative study was the first stage of a multi-stage research process. In the research approach of this empirical studies, we aimed to reveal information that helps to identify the most important marketing strategy decisions for the domestic beekeeping sector.

The purpose of the research was to explore qualitative information that helps domestic producers of honey in product development and sales issues. The semi-structured in-depth interviews provide a rich understanding of the subject.

The main topics of the in-depth interview guide were the following: honey buying and consumption habits, the attitudes towards domestic honey, attitudes related to honey consumption and the brand awareness of domestic producer honey.

The following filtering condition was applied: persons aged 18, participating in the consumption decision, consuming honey at least once a month. The data collection took place between March and April 2017, with 86 manuscripts in total being evaluated using a traditional content analysis method. The sampling technique was snowball sampling. The composition of the sample: we examined 86 in depth interview script, the number of male respondents 39, female 47. 7 respondent belongs to the 18-24, 17 to the 25-29, 27 were in 30-49 age group, 27 in the 50-64, and 8 was older than 65 years. Level of education: secondary education without graduation 18, secondary education with graduation 45, completed college or university, 23 persons.

## 3. RESULTS AND DISCUSSION

### 3.1. Associations with honey

In the first part of the interview, we asked the participants to formulate what they think of the word "honey", as illustrated in the word cloud of Figure 1.

It is clear that honey has a good evaluations of the respondents, as most associations have shown positive consumer attitudes.





When hearing the word honey, most consumers associated it to a food or drink prepared with honey, usually the most common was the tea. The consumers also mentioned coffee, honey-buttered bread, cakes, salads, roasts, honey pálinka, and cakes prepared with honey. Associations linked with cold winter, advent preparation, Christmas and gingerbread baking were also numerous, typically mentioned in third, fourth, and fifth places. Most of the consumer associations discovered have described typical situations of honey consumption, such as "the family breakfast together", "the gingerbread baking at Advent with mom and grandma", and "the Christmas family lunch and dinner". Almost all respondents mentioned the savoury sweet taste of honey, but less than half of those surveyed mentioned the other sensory characteristics of honey, such as associations of the yellow colour, dense, sticky texture and pleasant floral scent of honey. The taste references are typically the first, second and third mentions, while the other attributes are in the third, fourth and fifth positions.

Associations with nature formed the third most mentioned category, a significant share of respondents mentioned sunlight, sunshine, forest, field, flowers, loud twittering and buzzing bees. Often the healing effect of honey was mentioned, especially in the case of sore throat and cold. There were a significant number of people who referred to bee-keeping associations, such as trotting, whining, hives or spikes, but Pooh bear was also mentioned several times among young people. There were only two rather negative associations; they were typically mentioned at last. One was the relatively high consumer price of honey and the other was the high energy content of honey.

Based on the in-depth interviews, we can conclude that the respondents have generally positive attitude towards honey. This is in line with previous research results of Ref. [22]. The research findings of Ref [12] related to the relationship between honey and health are confirmed by this research. The references to health and to the favourable nutritional and physiological effects of honey took more than 20% of the total number of mentions. These findings are in line with the results of Ref. [12] that consumers are aware of the interrelated concepts of honey and health. On the basis of the remarks, we can conclude that the respondents consider honey to be a healthy natural sugar substitute with a valuable content.

We consider it particularly important that many respondents highlighted honey of Hungarian origin as a particularly good quality honey. There were a significant number of respondents, especially in the older age group, who first mentioned the Hungarian beekeepers when formulating high-quality honey.

### 3. 2. Consumer habits

In the survey, we examined the occasions, events and situations are most commonly associated with the consumption of honey. The primary cause of the consumption of honey was its healing power, its beneficial nutritional and physiological properties and its sweetening effect. The reason for consumption in all of the above mentioned references is the medicinal effect of 39% sweetening 34%, health preservation 27%. Consumers used this type of segmentation in Pocol's and Marghias's (2008) research when investigating Romanian consumer habits [23].

Consumers, who count themselves health conscious prefer to use honey as a sweetener, as well as the natural origin and valuable content of honey. Those segments, who take care to preserve their health through their food consumption, typically consume honey on a regular basis, "daily", or "several times a week". Those who like honey because of their healing effect, occasionally but continuously throughout the year, do not only belong to those who consume honey in the case of cold, but are also used for other treatments such as anti-inflammatory or prophylaxis. "I use rapeseed for reflux complaints and I feel that it has worked perfectly so far," "rapeseed is good for the stomach,"

Spontaneous mentions also showed seasonal growth in honey consumption, with more than three-quarters of the consumers surveyed consuming more honey in the cold, autumn and winter periods than in the rest of the year. "The linden honey is very good for sore throat and cold! In case of cold, in the winter, you should put two or three tea spoons of honey into the tea which is not too hot, so you can replace the sugar." "Many people use it only for sweetening, although it is also effective against diseases such as sore throat." "We use linden honey in case of cold." A small group of respondents, typically old people, can categorize

the healing properties of several varieties of honey: "... acacia honey can generally be used for of all kinds of cold, sore throat. Chestnut honey helps prevent thrombosis, buckwheat honey is good for circulation, blood pressure lowering, while linden honey can be used for like insomnia, fever, but also cough."

According to Ref. [24], seasonality can be observed in relation to the habits of honey consumers. From September to the end of December, the purchase of honey significantly increases compared to the rest of the year. The honey is usually consumed in the form of hot tea with honey: "Usually I consume honey several times during the winter, when cold is common, because on the one hand it is extremely healthy on the other hand, if I am sick the honey-lemon-ginger tea is the first..." "Normally, I consume one to two spoons of honey a day, adding it to tea or to coffee as a sweetener, but when I'm sick, I consume more." Some of the respondents use honey for injuries, homemade healing, typically externally: "it is excellent for bruises and wounds", "honey has a beneficial effect on my daughter's troublesome skin and my wrinkles". Many respondents have classified honey as a medicine that, through its disinfectant effect, is well suited for the treatment and prevention of certain diseases: "Every morning, I eat a spoonful of honey. With this, I protect my health and preserve myself from diseases." Another distinct group of consumers also consumes significantly more honey seasonally, during the Advent holiday season and at Christmas, usually in the form of festive foods, drinks, various honey cakes and gingerbread. A significant proportion of respondents associated honey with a food consumed by the family together and with a pleasant food that reminds them of their childhood: "The common family Sunday morning without the honey milk and butter-honey cakes is unimaginable!", "I always remember my mother and my childhood about honey, it was so good..."

It was repeatedly stated that honey was typically consumed as a part of the breakfast, which is in line with Ref. [25] research. The majority of respondents regularly consume honey in the form of food, typically as part of the breakfast: "I don't think I could start better a Sunday morning with a family like eating a butter-honey cake!" Regarding the day period of meals, after breakfast, morning and afternoon snacks were described frequently as honey meals while lunch and dinner were mentioned the less. According to the results, very popular honey dishes are cakes, gingerbread, buttered honey bread or cakes. Honey is also used for preparing roasted, pickled meat, salads, sauces and dressings.

Regarding the form of consumption, all respondents regularly consume honey in some form of a beverage. The most preferred beverages are tea, coffee, milk, cocoa, lemonade, cocktails and various alcoholic beverages: honey wine, honey beer and honey pálinka: "honey pálinka is my favourite spirit, tasty, sweet yet strong", "the lemonade with honey is my favourite", "the honey wine is a real specialty".

Especially for younger respondents, it was used as a performance enhancer for greater mental, physical effort, sports, learning: "Nowadays, health conscious nutrition has invaded and some people are trying to consume as little carbohydrates, especially sugar, as possible. To boost performance, honey is the best natural remedy". Honey is not only consumed as food and drink by the respondents. One third also uses honey for beauty treatment in a wide variety of forms: shampoo, balm, shower gel, body lotion, hair dye, face cream, scrub, facial mask, massage cream, lipstick, honey fragrance and furniture care.

Aside from honey, propolis, pollen, beeswax and royal jelly were mentioned as bee products. It has been mentioned in relation to hive products that they are difficult to reach for those who do not go to places where they can meet with beekeepers. Despite the difficult access, these products are very popular among consumers: "we consume propolis on a weekly basis, it is said to be a universal remedy", "the pollen is a real vitamin bomb!" "If there is trouble, I always turn to the healing power of the bees for help."

As a drawback, the price of honey and its fattening effect were mentioned: "You should not overdo your consumption due to the high sugar content." "I try to consume the right amount of everything, not much, or little, so is honey."

Thus, most of the respondents consume honey primarily because they want to protect their health, to contribute to the healthy functioning of their body, and to improve their well-being. The members of the younger generation mainly use honey as sweeteners, while the older generation does not only like it because of its sweetening effect, but is consumed for health preservation and is preferred for its healing properties.

### 3.3. Honey variety preferences

During the interviews, we examined spontaneous mentions of the varieties of honeys. There were 258 mentions, out of these: 74 for acacia honey, 65 for flower honey, 42 for linden honey.

In addition to the most popular honey varieties, Hungarian honey specialties were also popular, such as various flavoured honey or honey with dried fruits and seeds. The variety of flavoured honey can be found at the producers. The respondents mentioned the following products: elderberry, lemon grass, chilli pepper, garlic, dill, cinnamon and mint honey. Among the honey varieties made with the addition of dried fruits and seeds the following were mentioned: mixed seeds with acacia honey, walnuts, hazelnuts, poppy seed, coffee, candied orange and pumpkin seed honey.

Acacia honey is the most popular flavour: "The acacia honey has a pleasant texture and great taste, I use it almost every day!" "I prefer the acacia honey. I tried the rest, but the acacia honey has the best taste." "The price of acacia honey is being hampered by its price" "Unfortunately, I buy the cheaper variety. I would buy Acacia, but the mixed flower honey is cheaper."

Adhering to the usual flavours is typical: "I noticed that in my family and among my friends, these are the varieties of honey that they use and buy again, so they do not change to another type of honey. To tell you the truth, I rarely buy a different kind of honey, I don't know why this is so, just the habit."

Consumers prefer to consume well-known honey of identifiable origin, typically preferring honey from a producer. Reliability and quality were highlighted as reasons. "I prefer domestic honey, because the honey that the bees collect from the plants in our environment is better for our body and I support the Hungarian economy, I trust the Hungarian products better." "Producers are more reliable, we get quality", "personal guarantee and trust", "honey from a producer is better and more beautiful".

The local beekeepers are considered to be of reliable origin, and the Hungarian honey is clearly described as a high quality.

## 4. CONCLUSIONS

In our research, our main goal was to get to know consumer associations, the most notable features of consumer preferences, and to analyse the consumer perception of Hungarian honey. We analysed the preferences of 86 consumers towards honey consumption. Based on our results, it can be stated that when the word honey is used, consumer associations are mainly referred to as honey dishes and drinks, pleasant taste and health. For the majority of the respondents, the domestic honey reminds us of good quality and reliability. It is important that the purchased honey is of domestic origin, it is also important to know the producer. The respondents tend to turn to the Hungarian producers' honeys that are considered to be healthier, better-tasted and also certified. This tendency is a huge opportunity for the Hungarian beekeeping sector. Effective labelling is important. Its exact geographical origin gives the consumer confidence in the product. For another important segment of honey consumers, honey is consumed only seasonally or while being ill. The most important factors for them are easy availability and price. The most popular among the honey varieties is acacia honey, which has been mentioned as the favourite variety for all segments.

The present research confirms that consumers' image of honey is clearly positive. Consumers consider honey to be a healthy food and natural sweetener, which, besides its traditional character, carries unique values. In terms of areas of application, health preservation, sweetening and cosmetic use have also emerged.

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## THE KEY ELEMENTS OF CONDUCTING LOAD-TO-FRACTURE MECHANICAL TESTING ON RESTORATION-TOOTH UNITS IN RESTORATIVE DENTISTRY

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### ABSTRACT

Biomimetic restorative dentistry strives to replace lost tooth tissue by biomaterials with similar physical properties. In order to do so, mechanical testing of dental restorative materials on their own and later in dental cavities is highly important. During this process dentists and engineers are collaborating aiming to set the indications of certain restorative materials and application techniques. In vitro fracture resistance testing of a restored tooth is one of the most important tests to be carried out during the indication setting process. However, for this specific test and received results to be valid for clinicians, the group conducting the tests must pay attention to mimic intraoral conditions as much as possible. The article aims at identifying the key elements of fracture resistance tests in dentistry. Adequately conducting this test is a prerequisite for later testing in in vivo conditions the restorative techniques that produced the best results among the in vitro tests.

Keywords: mechanical testing, fracture resistance, fracture pattern, restored tooth, load-to-fracture

### 1. INTRODUCTION

The aim of restorative dentistry is to restore the function and esthetic appearance of teeth after previous dental hard tissue loss due to caries, trauma or parafunctional jaw movements. Any dental restorative or prosthetic material used for this purpose must have sufficient mechanical integrity to function in the oral cavity for an extended period of time. Thus, testing the mechanical properties of these materials on their own and also luted to dental structures is highly clinically relevant. This is supported by the fact that the two main causes of failure identified in case of dental restorations are fracture (restoration and/or tooth) and secondary caries. Complete cusp fracture of posterior restored teeth is a common phenomenon in dental practices with incidence rates varying from approx. 20 to 71 per 1000 person-years at risk [1]. Fracture shows a higher tendency in vital teeth with large direct restorations, in root canal treated teeth restored with direct restoration, and in neglected cariously infected teeth.

Thus, the restoration should provide adequate fracture resistance to the damaged tooth and also, if fracture occurs, should direct the fracture away from the center of the tooth for it be restorable later on. This means that some restorative materials (placed on the outside) must be hard and wear resistant, while some materials (placed in deeper layers) must be more elastic and have adequate fracture toughness to be able to stop possible crack propagation [2].

Once a restorative material has been analyzed and tested regarding its mechanical properties, testing it in certain in vitro dental indications should be performed. For this purpose intact human teeth extracted for other reasons (periodontal infection or orthodontic treatment planning) are used widely. One disadvantage when using human teeth for testing is the large variation among individual teeth, e.g. in the mechanical and physical properties, and existing microcracks in the dentin may not always be seen before testing. On general this may lead to large standard deviations.



Despite the mentioned shortcomings, the use of natural human teeth is a reliable methodology in fracture testing and still represent the first choice for in vitro tests [3]. When utilizing human teeth, setting strict exclusion and inclusion criteria are mandatory. For mechanical testing the most often used inclusion criteria are the following: visual absence of caries or root cracks, absence of previous endodontic treatment, posts or crown or resorptions. Teeth with severe polymorphism of the coronal structures should be excluded from the study and careful attention must be paid during measuring the coronal dimensions of the tooth and/or the prepared cavity to insure standardisation [4]. Also, teeth should be used within 2-6 months after extraction and they must be kept in specific solutions before usage.

Usually the first and most important step when testing tooth-restoration units is measuring fracture resistance. This can be performed in a static load-to-fracture setup with a universal testing machine. As stated by Ref. [5] static loading is usually the first step in the evaluation process of a novel dental materials and related techniques and is commonly used in order to obtain basic knowledge regarding the fracture behaviour and load capacity of a restored tooth. There are a number of factors that may interfere with resistance to fracture, such as the differences between specimens, tooth embedment method, type and direction of load application, crosshead speed, and simulation of thermal or mechanical fatiguing [6]. During this test intraoral conditions should be mimicked as much as possible. During the embedding of the samples two important elements should be emphasized: simulating the periodontal ligaments and simulating the bone level around the roots. In order the best mimic the elastic property of the periodontal ligaments, which normally connects the roots to the bone in a healthy clinical situation, the root part of the samples is covered with a layer of liquid latex separating material prior to embedding [7] (Figure 1.).



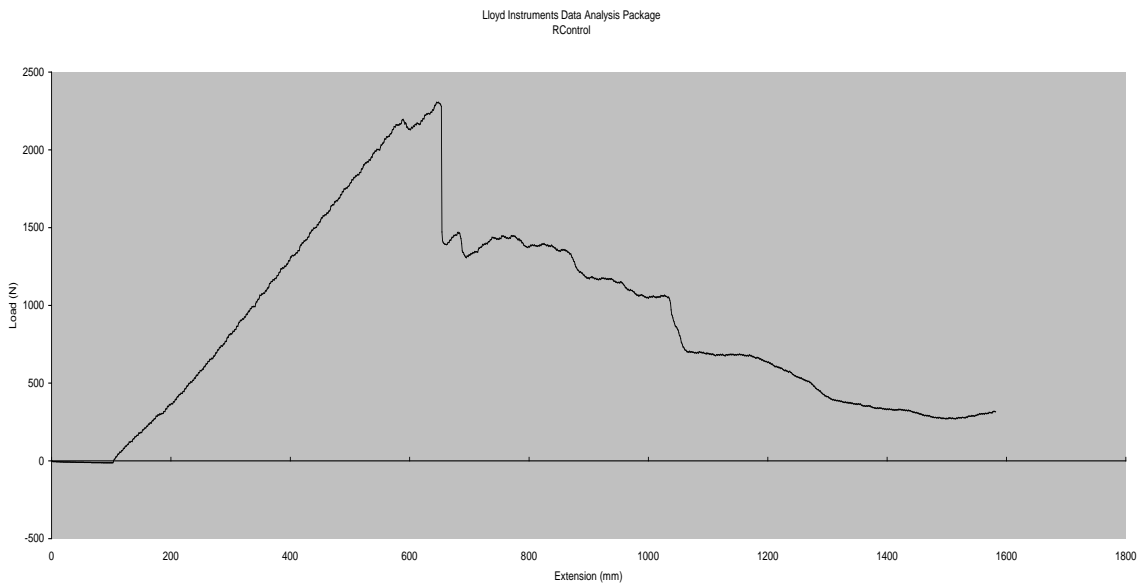
*Figure 1. A layer of latex separator applied on the root surface before embedding.*

This is highly important as the ligaments provide a 0.05 mm movement for the teeth in the bony socket, thus it absorbs stress to a certain amount before transferring it to the bone. This is also visible in mechanical testing if the latex is applied on the roots of the specimen. Although some studies do not use any separating agent on the root surfaces before embedding them, most studies highlight the lack of periodontal ligament simulation as a limitation of the design of these studies with regard to their clinical relevance [8]. During the embedding procedure teeth are embedded in metacrylate resin, usually 2 mm apical from the cemento-enamel junction (CEJ) to simulate the bone level. This represents a healthy situation regarding the amount of bone supporting the tooth. To our knowledge only Szabó et al. examined the effect of altered bone level on the fracture resistance of root amputated molar teeth [9, 10]. In their studies the embedding was positioned at a more apical level to simulate a root furcation involved situation, which develops in periodontally compromised patients.

Once the samples are embedded, they need to be positioned under the rounded cylindrical bar delivering the loading, according to the type of tooth to be tested. In molar teeth the bar is positioned at the centre of the occlusal surface of the tooth crown between the buccal and oral cusps. This way a tripod contact is created by simultaneous and equal contact of the bar to the mesiobuccal, distobuccal and lingual cusps while the tooth is loaded from a vertical direction parallel to the long axis of the tooth. Contrary to molar teeth, an oblique load (45 degrees to the long axis of the tooth) is applied to the occlusal incline of the buccal cusp in premolar teeth [11]. This pattern of loading is intended to simulate normal working side occlusal contacts. This should represent a worst-case occlusal loading scenario for these teeth and test the integrity of the tested restorations and tooth structure. In case of anterior teeth the loading tip is positioned at a 30-45 degrees to the long axis of the tooth in order to simulate the normal relationship of the front teeth. The bar delivering the loading is usually a rounded, 6 mm diameter stainless-steel ball-shaped stylus [12]. Some research groups were trying to incorporate a more realistic relationship and contact with the opposing dentition into their mechanical studies. With this intent Soares et al. are using a 6-7 mm diameter composite resin sphere as a loading tip [13]. As composite shows similar wear to human enamel, the utilization of such sphere for loading could be beneficial, but more when dynamic loading is applied rather than static load-to-fracture.

The crosshead speed (speed of loading) also needs to be set prior to loading. Molar teeth are usually loaded at 2 mm/min. [14], whereas premolar and front teeth are usually loaded at 0.5 mm/min. speed [15]. One can diverge from these numbers, as all specimen will be loaded at the same pace the difference between the groups are important, not the actual speed itself [16]. During the test a force vs. distance curve is dynamically plotted for each tooth. Failure load, which can be defined as the load at which the tooth-restoration complex exhibited the first fracture and results in a peak formation on the force versus distance curve, is recorded in

Newtons (N). In each test the specific failure load is determined when the force versus distance curve showed a sudden change in load, which indicates an abrupt decrease in the specimen's resistance to compressive loading (Figure 2.).



**Figure 2. Force (load) versus distance (extension) curve**



This sudden drop in load does not necessarily refer to the fracture load in all cases. If the two values are not the same, then the initial failure is a much more significant and useful parameter than the fracture resistance from a clinical standpoint. This is due to the fact that once a detectable crack (indicated by the drop of load) occurs, penetration of oral fluids would lead to decay formation and a reduction in the longevity of the restoration in the oral environment. Therefore, initial failure must be detected when present.

Furthermore, apart from determination of the load required for fracture, evaluation of the fracture type is important from a clinical point of view. Thus, whenever conducting a load-to-fracture test, not only the fracture resistance, but also the failure mode should be evaluated. After the mechanical testing, the fractured specimens are examined regarding their fracture patterns. According to Scotti and co-workers, distinction is made between restorable or nonrestorable fractures under optical microscope with a two-examiner agreement. Based upon their evaluation system, a restorable fracture is above the CEJ, meaning that in case of fracture the tooth can be restored, while a nonrestorable fracture extends below the CEJ and the tooth is likely to be extracted [14] (Figure 3).



*Figure 3. Fracture pattern deemed unrestorable as it extends under the CEJ.*

Fracture resistance and fracture pattern must be interpreted together as a restoration that shows only high fracture resistance but unfavorable fracture pattern in case of fracture cannot be deemed the best solution among other restorative materials and techniques. The ideal solution will be the one with fracture resistance not different from an intact tooth (the control group in the studies) and with dominantly favorable fracture pattern [17].

The drawback of load-to-failure tests is that the continually increasing load applied to the teeth is not typical of the type of loading that occurs in clinical conditions, in which failures occur primarily due to fatigue. Also the load at which the specimen fracture are sometimes way higher than the values registered at a normal biting event. In the front region the average biting force is between 100-300 N, this increases to 400-500 N in the premolar teeth, and further increases to 600-800 N in the molar region. Although forces range from 8 to 880 N during normal mastication, but it must be emphasized that greater loads have been described in bruxism, and teeth in this region may be exposed to extremely high forces when accidentally biting on a hard object or in trauma.

Such extreme forces cannot be completely absorbed, therefore the restorations placed and made in teeth, especially in the posterior ones, should be able to withstand much higher loading than the ones manifesting during normal biting forces and movement. Such high forces will continue to rise with the high prevalence of temporomandibular disorders leading to bruxism in modern Western societies [18]. As pointed out by Deliperi et al., during a tooth's lifetime, a wide range of overload events may happen, including those from bruxism, trauma (high extrinsic loads), or during dynamic loading (intrinsic chewing strokes in a small area due to a hard foreign body such as a stone or seed) [19]. Therefore load-to-fracture tests are resembling a possible traumatic event, or biting on a foreign object, or just the condition potentially present in a bruxing patient's mouth.

## 4. CONCLUSIONS

Despite its limitations, fracture testing remains a common experimental method of evaluating restorative procedures for restored teeth. In the future, load-to-fracture tests should be accompanied by dynamic loading and fatigue testing, which better mimics intraoral loading conditions.

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## POSSIBILITIES OF OPTIMIZING FUEL CONSUMPTION IN HYBRID AND ELECTRONIC AIRPLANES

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### ABSTRACT

The automotive industry was always characterized by innovation and the use of cutting edge technology. Daily we can see vehicles packed with technological advancements. The main focus of the current technological trend is electric drives. With the rise in popularity of electric cars more types of vehicles are adapting electric drives. In the case of airplanes the standards are higher than in the case of cars so the emphasis of research and innovation is greater. This paper presents a list of the challenges electric aircrafts face and their potential solutions. Currently many of these problems currently only have partial solutions if any. There is also a comparison between the properties of materials used and the expectations for hybrid aircraft. A comprehensive model was created taking into account the criteria set for hybrid and electric aircraft. With the aid of the model the effect of the most important components on efficiency can be assessed.

Keywords: hybrid and electronic airplanes, fuel consumption, optimization model

### 1. INTRODUCTION

With the increasing of the greenhouse effect even more concern is placed on the reduction of harmful emissions in air travel. Based on the Strategic Research & Innovation Agenda (SRIA)[1] of the Advisory Council for Aeronautics Research in Europe (ACARE) the International Air Transport Association (IATA)[2] and the European Commission (EC)[3] announced long-term environmental protection goals. The plans may seem ambitious looking at the technologies currently being used.

The main focus is on the reduction of the energy needed for propulsion. The goal is a 30% decrease in the needed propulsion and power by 2035. A 70% decrease in carbon dioxide emission is the goal by 2050.

By 2020 an estimated 20% decrease is expected in the energy needed for propulsion and power compared to the reference data from 2000. The efficiency of the drive holds the key to the greatest reduction in carbon dioxide emissions [4].

Figure 1 shows the efficiency of currently used drives and the goals set by the strategy. Figure 1 shows the total overall efficiency of the airplanes drive during flight  $\eta_{ov}$  (overall efficiency) compared to the reference year of 2000. The graph shows two types of efficiencies the product of the two gives the aforementioned overall efficiency. The vertical axis shows the efficiency of the propelling force  $\eta_{pr}$  (propulsive efficiency) while the horizontal axis shows the internal or thermal efficiency  $\eta_{in}$ .

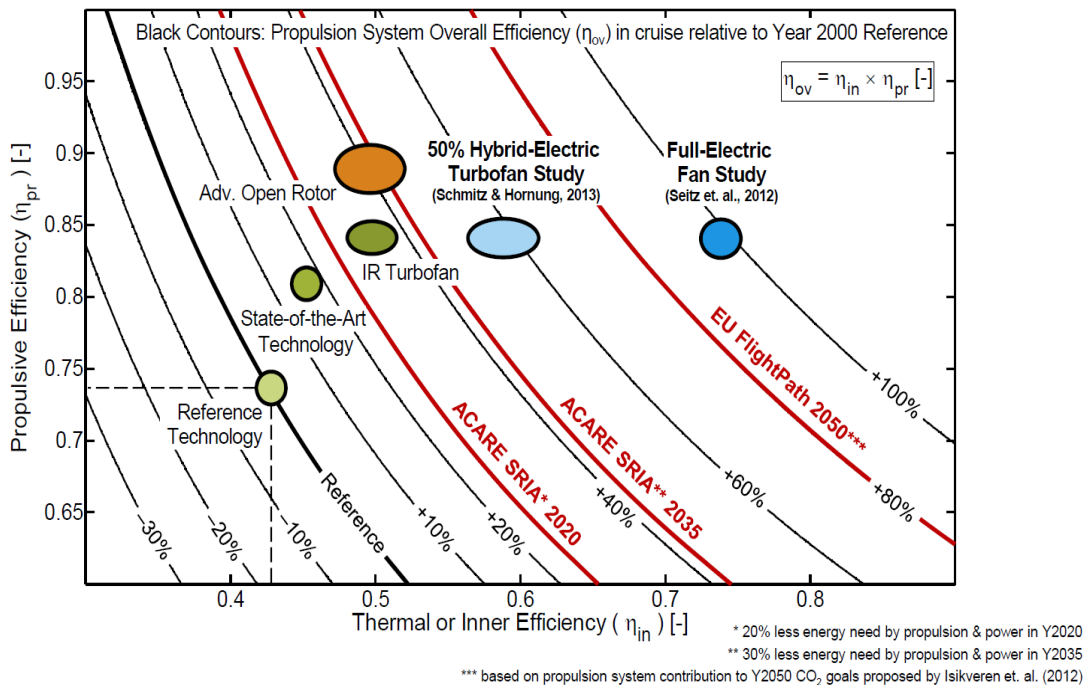


Figure 1. Propulsion systems overall efficiency

The graph shows that the goal of ACARE by 2035 is to increase total efficiency to 43%, while setting an 80% increase by 2050, which can be achieved by improving both types of efficiency. The current state of the art engines efficiency is 15% above the efficiency of the year 2000 baseline model. Improving on the advanced gas turbine based concept [4] we can expect an efficiency of about 50% or more which fulfils the efficiency goals set by 2020. The greatest increase in propulsive efficiency can be expected from the Open Rotor (OR) and the Turbofan drives.

The limits of the drives can be exceeded with the introduction of electrical energy. Figure 1. shows the efficiency of hybrid and fully electrically driven air funnel propeller drives [6][7]. From the studies we can see that electrifying the turbo drives efficiency of 50% is expected to reach the efficiency goals of 2035, while converting to a fully electric drive is expected to yield an efficiency of nearly 100%.

## 2. HYBRID ARCHITECTURES AND HYBRIDIZATION

To increase efficiency and lower fuel consumption it is paramount to choose an appropriate drive architecture. Electric drives can be characterized with drive configurations, these configurations share a few key components such as motor, generator, battery and energy converter, in short **power management and configuration (PMAD)** systems. Studies usually separate electric drives into three main groups [5][8]:

- All electric propulsion
- Turboelectric propulsion
- Hybrid electric propulsion

The mentioned solutions mostly differ in efficiency, carbon dioxide emission and noise pollution.

### 3. ALL ELECTRIC PROPULSION

In the case of all electric propulsion all energy required is stored in the battery. Total efficiency  $\eta_{ov}$  is almost 90% [9] and since in this case we don't need conventional engines only electric carbon dioxide emission can approach nearly 0. Another important aspect is the noise level since with the absence of combustion noise pollution ceases.



Figure 2. Block diagram of all electric propulsion system

### 4. TURBOELECTRIC PROPULSION

Turboelectric systems do not rely on batteries to store electrical energy. The total turbo electric system is made up of a turboshaft motor with turns a generator which in turn spins the electric motors that move the propellers (Figure 3a). In a partial turboelectric system both engines are used for propulsion. Meaning the turboshaft motor only uses a portion of its output to drives the generator (Figure 3b). The most important aspect of this type of drive is that the turboshaft motors can be operated in their optimal efficiency range regardless of the needed torque.

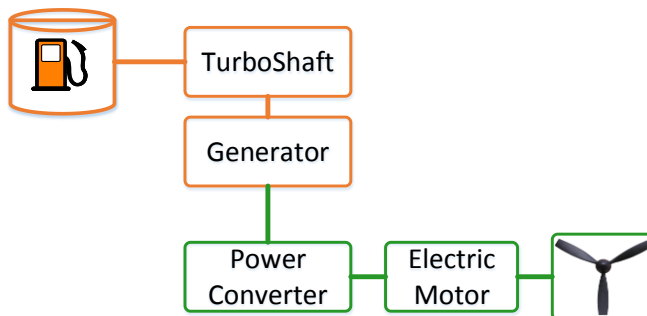


Figure 3a. Block diagram of total turboelectric propulsion system

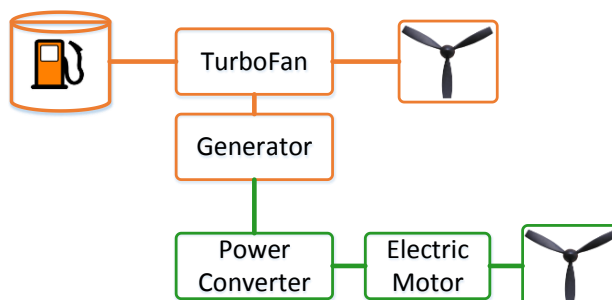


Figure 3b. Block diagram of partial turboelectric propulsion system

## 5. HYBRID ELECTRIC PROPULSION

Hybrid drive systems come in a variety of architectures. Most commonly used ones are the series hybrid and parallel hybrid architectures [10]. Figure 4 shows a series powertrain which is the simplest one. The shaft of the propeller is spun by the electric motor. Turboshaft motors spin the generators and provide energy to the battery or the electric motors. This means that the gas turbine can run at its optimal range thus lowering fuel consumption and the exhaust of harmful burn products.

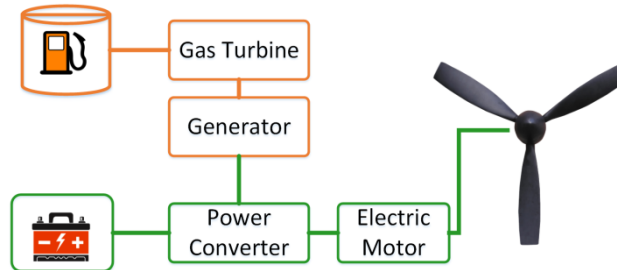


Figure 4. Block diagram of series hybrid propulsion system

A further advantage is that a typical gas turbine can be smaller to meet the average energy needs. To meet the demands of the needed power the size of electric motors and batteries has to be larger. taking into account the weight of the generator this means a substantial increase in weight compared to the parallel architecture [11]. For ground vehicles this is not such a problem, but for airplanes this is an important question. Another drawback is the power loss due to power conversion since we convert the mechanical energy of the gas turbines to electric energy and then back again to mechanical with the electric motors to drive the propellers there are substantial losses [12]. In the case of parallel hybrid configurations mechanical and electric power is funnelled in parallel to the gearbox as shown in Figure 5.

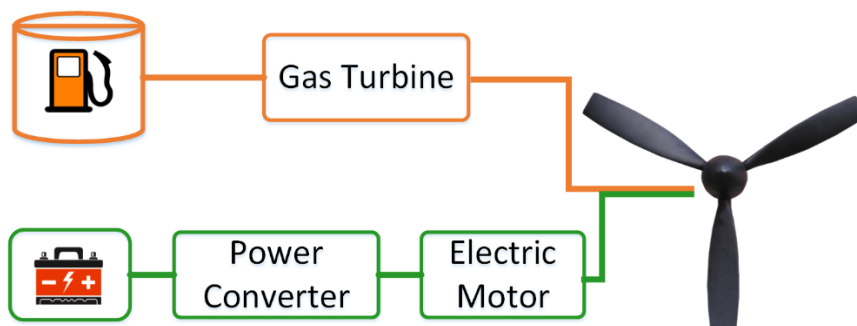


Figure 5. Block diagram of parallel hybrid propulsion system

An advantage of this architecture is that there are only two motors with their own power sources. Because of this we save on weight which in the case of air travel is important. A further advantage could be that the two separate drives increase reliability. Perhaps the greatest disadvantage is the increase of complexity of the drive and the controller since the energy required for propulsion comes from two sources these have to work together.



The most common strategy in the case of hybrid electric cars is that the gas turbine works all the time with constant load where it's most effective. The electric motor is used when additional power is needed (like in the case of takeoff). If the energy needed for the propeller is less than what is provided by the gas turbine the remainder can be used to recharge the battery, this is achieved by using the motor as a generator. The combining of the series and parallel architectures brought the series-parallel hybrid and complex hybrid architectures. These architectures combine the advantages and drawbacks of both series and parallel architectures. They are unusable for flying mostly because of their weight.

## 6. MEASURE OF HYBRIDIZATION

When having more than one drive in a vehicle the tuning and handling of them becomes a real challenge. In the case of hybrid vehicles the electric drive needs to connect to the system so that it provides maximum efficiency. Because of this some new variables come into play [13]. One of the key variables is the measure of energy hybridization which is the ratio of the electric energy to the total energy.

$$H_E = \frac{E_{bat}}{E_{tot}} = \frac{E_{bat}}{E_{bat} + E_f} \quad (1)$$

Where  $E_{bat}$  is electrical energy and  $E_f$  is the energy coming from the fuel. The measure of energy hybridization is not an ideal indicator since the specific energy of the fuel is much greater than the specific energy of the battery while the efficiency of electric drives is far greater than the efficiency of gas turbines. Because of this reason we use the power hybridization indicator as well [10].

$$H_P = \frac{P_{el}}{P_{tot}} = \frac{P_{el}}{P_{el} + P_{th}} \quad (2)$$

Where  $P_{el}$  is the power of the electric motor and  $P_{th}$  is the power of the gas turbine. For conventional airplanes the measure of hybridization is 0 since all the energy comes from the burning of fuel:  $H_E = 0$  and  $H_P = 0$ . In the case of turbo-electric airplanes all energy is all propulsion is from electric motors that are powered by gas turbines giving us  $H_E = 0$  and  $H_P = 1$ . In the case of fully electric airplanes we have  $H_E = 1$  and  $H_P = 1$ . This means that all energy is from the battery and all propulsion is from electric motors. In practice this indicator is not always applicable since an airplane with a large electric motor that is used sparsely gives a large power hybridization value while in reality during flight it's only hybrid for a short time.

For this reason another parameter the produced power ratio [14] ( $\Phi$ ) is used which is the ratio of the power exerted by the electric motor and all the power exerted during flight.

$$\Phi = \frac{E_{em_{tot}}}{E_{pow_{tot}}} \quad (3)$$

In the case of a traditional airplane  $\Phi=0$  while at a fully electric airplane  $\Phi=1$ . A further example  $\Phi=0.4$  means 40% of the energy for flight came from the electric drive and 60% from the gas turbines.

## 7. ENERGY STORAGE

Energy storage is the most crucial criteria when designing a hybrid airplane. Traditional aircraft use fuel with a far larger specific energy (12000-13000 Wh/kg) [15] than in the case of batteries. The specific energy of batteries needs to increase in accordance with economic and ecological expectations. Figure 6 shows a Ragone diagram which is used to describe the current levels of batteries where the specific power and energy are shown on a logarithmic scale. An optimal combination is where both are fairly high.

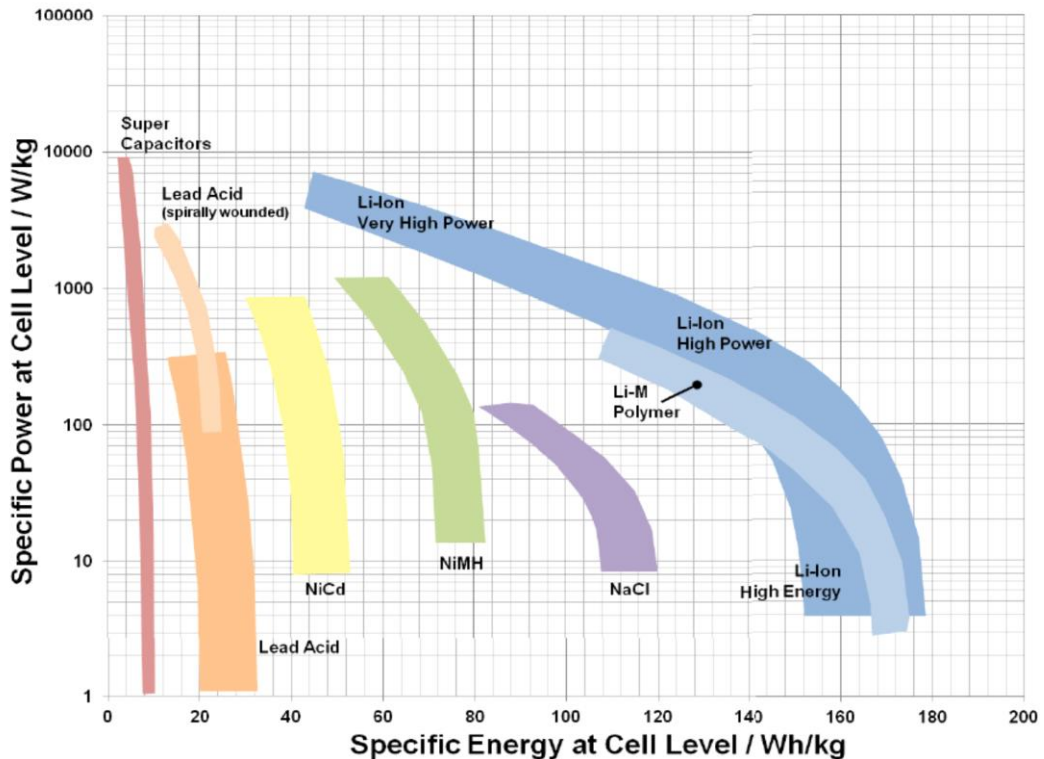


Figure 6. Ragone diagram for specific Energy and Specific Power [15]

## 8. LI-ION AND LI-POLY BATTERIES

Lithium-ion and Lithium-polymer batteries are the most used batteries on the market thanks to the ideal placement of both characteristics (Figure 6.). Lithium-polymer technology has a similar characteristic. The power of the Lithium batteries is determined by the materials used for the electrodes. The state of the art batteries positive electrode is made of Lithium-metal-oxide (mostly cobalt and manganese) while the negative electrode is made of graphite, these batteries have a specific energy of 300 Wh/kg and have a specific power of less than 100 W/kg. These values are not enough for a typical flight. For example a Tesla Model S P85 electric car has a Li-ion ESD (Energy Storage Device) which has a maximum continuous power of 311W and a total stored energy of 85 kWh. The mass of the battery is 540 kg so it has a specific power density of 575 W/kg and a specific energy density of 157 Wh/kg.

In the studies made by the Safran company [17] they show that a smaller airplane would need a battery with a specific energy density of 500 Wh/kg while a bigger passenger carrier would need between 600 and 750 Wh/kg. The above mentioned Li-ion and Li-polymer batteries provide a good basis for the electric and hybrid cars of our age, but are inadequate for hybrid airplanes.

## 9. LI-AIR BATTERIES

Lithium-Air batteries hold a lot of promise. This technology has a theoretical specific energy of about 11500 Wh/kg which is close to the specific energy of gasoline. They have a major flaw that needs to be solved first which is their short lifespan. After the third charging cycle the capacity of the battery is greatly reduced, making this technology unsuitable for aircraft use.

## 10. LI-S BATTERIES

Currently Lithium-Sulphur batteries are the most promising energy storage devices [19], because compared to Li-ion batteries they have a large specific energy. The theoretical maximum is 2567 Wh/kg at 2.2 volts. Currently the OxisEnergy company [20] sells these type of batteries which have a specific power of 300 Wh/kg and plan to double this value in the next five years. These batteries are characterized by a Lithium anode and a Sulphur cathode as seen on Figure 7.

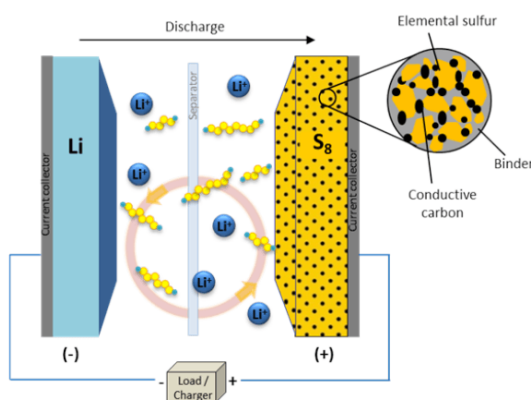


Figure 7. Lithium-Sulphur battery cell

In the discharge process the lithium reacts with the sulphur to become  $\text{Li}_2\text{S}$ , which in the process of recharging breaks up into its components. The problem with Li-S batteries is their lifetime currently they last for 500-1000 charging cycles, the manufacturer plans to increase this to 1500-2500 cycles in the next few years. On a positive note they have a low production cost of about 250 euros/kWh compared to Li-ion which have a price of 475 euros/kWh.

Following the trend of the Li-S batteries by 2021 we can expect a specific energy of about 500 Wh/kg, 650 Wh/kg by 2030 and 1000 Wh/kg by 2040. These values are adequate for use in hybrid airplanes.

## 11. ELECTRIC MOTORS

The second main pillar of hybrid and electric vehicles is the electric motor. Thanks to electric and hybrid cars these have also advanced quite a bit. More power with less loss, weight and size these are the most important criteria for flying applications. The Siemens company has made excellent headway in this field thanks to its intense research strategy [21]. These motors have an efficiency of 95% and are quite light, their power density ( $W_{sp}$ ) exceeds 6 kW/kg. It can be easily redesigned for smaller or larger applications, making it ideal for large or small aircraft.

The following criteria need to be taken into consideration:

- The use of high performance magnetic materials for higher torque density
- High performance cooling to increase the efficiency of the motor
- The optimization of passive elements to make use of advanced manufacturing techniques such as 3D printing
- Optimizing the rpm range of the motor ideally removing the need for a gearbox

Taking these criteria into consideration Siemens made their SP260D induction motor (Figure 8.) which has a maximum continuous power of 260 kW at 2500 rpm and a total mass of 50 kg. The power density of this motor is at least 5 kW/kg. This motor has been installed and tested on the Extra 330 LE airplane.



*Figure 8. Siemens SP260D electromotor*

In future automotive and aircraft applications the so called high temperature superconducting (HTS) motors can be used. These motors cooled by liquid nitrogen can have an internal resistance of 0 thus having high power density. Their only drawback is that they need constant cooling which uses mostly liquid nitrogen. Currently available HTS motors fall short of expectations having 30 kW-s of power with a 110 kg engine [22]. Their power falls short compared to the SP260D, but HTS motors are relatively new and research shows that a power density of 20 kW/kg is possible.

## **12. THE MATERIAL AND STRUCTURE OF AN AIRPLANE**

Other than the mass of the above mentioned motor and battery one of the most important parameters is the mass of the fuselage and its structure.

## **13. THE MATERIAL OF AN AIRPLANE**

Modern airplanes use carbon and glass reinforced composites [24]. The two components of the composites are the matrix and the reinforcement. The composites were developed for combining the benefits of the different materials' advantageous physical parameters. The first "modern" composite (used even today) was the textile-bakelite that is a phenol formaldehyde resin enhanced by textile fibres. The resin is a really rigid, frangible and weak plastic and only the enchantment with natural textile fibres made it suitable for wider industrial applications. The first composite applied in aircraft industry in bigger amount was a one-

direction strip named GORDON AEROLITE developed by Aero Research Ltd. that was an untwisted line string impregnated by phenol resin in the '30s. The next step was the "marriage" of the high strength fibre glass and the polyester resin that was used first in 1943 for the rear part of the fuselage of a trainer plane (Vultee XBT-16) made in the USA with a honeycomb structure sandwich panel. In the aircraft industry appeared the epoxy-resin matrix materials that were first reinforced with fibre glass then carbon-, graphite- or aramid-fibres, boron-fibres, ceramic fibres or the combinations of them [25].

Currently polyimide and bismaleimide basic thermosetting resins and thermoplastics are more significantly used for bedding the reinforcing fibres due to their higher temperature tolerance. Nowadays the modern composite materials are widely used for the airframe structure of the lightweight sport and general purpose airplanes and of the new generation military attack and fighter planes and helicopters. The reinforcing fibres of the composite materials have high tensile strengths and high Young-modulus, but their density is much lower than of the metals and in addition their structure can be anisotropic (generally orthotropic). In the workshop of the University of Szeged, Faculty of Engineering, Department of Technology standard specimens were produced and the composition of metals were investigated (Figure 9.).



*Figure 9. Investigation of a lightweight, fixed-wing airplane built for sport purpose [24]*

## 14. THE STRUCTURE OF THE AIRPLANE

Several have been developed in the history of aircraft design. With the advance of airplanes the position of the wings, engines, rudders changes even to this day. The configuration of gas turbine aircraft is vastly different from hybrid and electric aircrafts and requires different considerations from the designer. Several studies were conducted to explore which configurations are most optimal for hybrid and electric aircraft [23]. The result of these studies present 35 possible configuration which merit further research (Figure 10.).

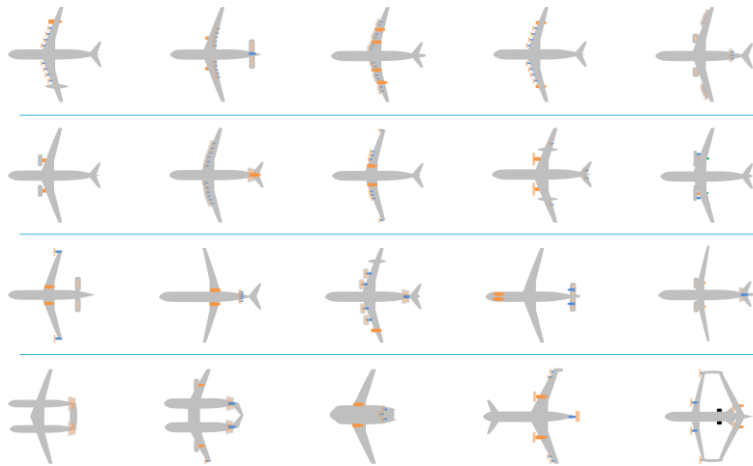


Figure 9. Illustration of 15 out of a total of 35 proposed concepts

## 15. DEVELOPING AN OPTIMIZATION MODEL

The topics discussed in previous subchapters all contribute to the optimization of hybrid and electric airplanes. Several other parts could also contribute to the optimization process (such as drive electronics, choosing the optimal cable size etc.), however we will omit these. During our research we aimed to create a model that takes into account the most important facets of optimizing the efficiency of an aircraft. These facets are: the architecture of the drive, energy storage, electric motor selection, the structure and material of the aircraft. These are the facets that impact the basic manoeuvres and thus the flight duration, quality of flight, safety, fuel consumption and efficiency (Figure 10.).

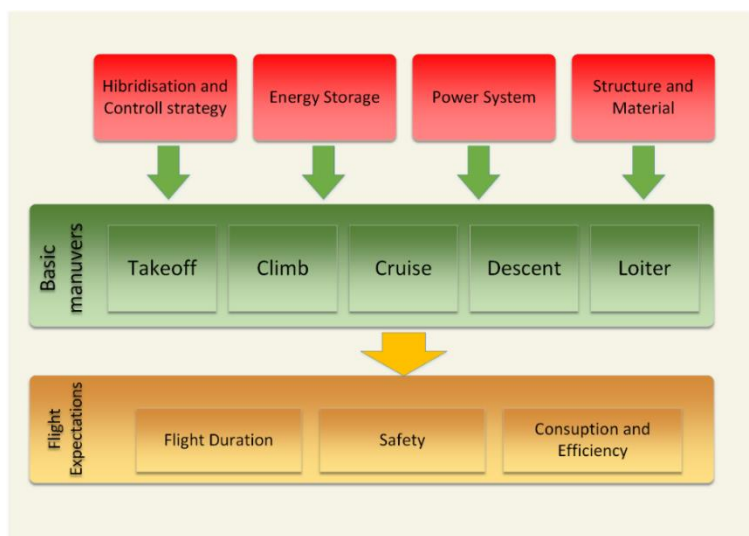


Figure 10. Illustration of 15 out of a total of 35 proposed concepts



In the modelling of fuel consumption usually only 5 base manoeuvres are taken into consideration [15]:

- Take-off: this is simulated to have a realistic power requirement and energy consumption, by considering the two phases of ground run and airborne acceleration.
- Climb: the aircraft climbs from airport altitude to cruise altitude and accelerates from take-off to cruise speed.
- Cruise: this phase is carried out at a constant altitude and true airspeed.
- Descent: the dual of climb phase, it starts at cruise speed and altitude and ends at loiter speed and altitude, using the same strategy considered for climb.
- Loiter: this phase is considered both for possible deviations and for actual hold above the destination airport.

With the optimization of these base manoeuvres we can impact flight time, safety and fuel consumption. The hypothetical model tries to optimize by taking into account in a simplified way the effects of the base components on hybrid and electric airplanes fuel consumption. Individually it wouldn't try to classify their effects since can be several future solutions which effects on fuel consumption are unknown.

## 16. CONCLUSION

With the rise in the greenhouse effect stricter standards are placed on aircrafts. The plans laid out by the International Air Transport Association and the European Commission has set ambitious goals. We checked for possibilities to meet these expectations. The state of the art and future trends of the most crucial elements of the aircraft have been examined. Their effect on fuel consumption in electric and hybrid aircraft was examined. The data revealed that several components currently have the ability to be used in electric or hybrid aircraft, yet many still need further improvements. Currently the batteries capacity needs the greatest improvement. Several advances were presented sadly they currently do not meet the set requirements to be used. We presented our findings in a model which shows the effect of these components on an aircraft's fuel consumption. This model may only be partial but serves as a baseline for further studies.

## 17. ACKNOWLEDGEMENTS

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