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A lakossági hipo- és hipermineraliémiáról

Hypo- and hypermagnesemia of the Hungarian population

Különböző típusú növényi olajok fizikai-kémiai tulajdonságainak összehasonlítása sütés előtt és után • Műanyaggal és hagyományos táptalajjal etetett *Tenebrio molitor* lárvák megkülönböztetésének lehetőségei • Nemzeti szabványosítási hírek

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TARTALOM – CONTENTS

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A lakossági hipo- és hipermineraliémiáról

Kulcsszavak: hiponatrémia, hipokalcémia, hipokalémia, hipomagnezémia, étrend-kiegészítő

1. Összefoglalás

A hazai epidemiológiai adatok azt mutatják, hogy a magyar lakosság nem szenved általános ásványi anyag-hiányban. Érdekes módon, a külföldi tapasztalatoktól eltérően, itthon inkább kalcium és kálium hiány, valamint magnézium többlet a jellemző. Ebből következik, hogy Magyarországon a hiány pótlására, de a magnézium-pótlás visszaszorítására kellene törekedni. Ezt elsősorban preventív intézkedésekkel, az étrend és élelmiszerek helyes megválasztásával célszerű megvalósítani. A nem megfelelő ionpótlás ugyanis veszélyeket hordoz, ezért csak indokolt esetekben és célzottan kell ezt választani.

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2. Bevezetés

Hipo- és hipermineralémiáról akkor beszélünk, amikor a beteg vérparamétereiben az ásványi anyagok ionkoncentrációja a normálérték (**1. táblázat**) alatti vagy fölöttiértéket mutat. Az ásványi anyagok (elemek) testünk szerves részét képezik, testtömegünknek mintegy 6%-át teszik ki. Ezek az elemek oldott formában, elektrolitokként részt vesznek a só-víz háztartásban és a sav-bázis egyensúly fenntartásában, de kötött formában szinte minden biokémiai reakcióban megtalálhatók. Mennyiségük és arányuk – bizonyos szűk határok között – konstans, erről a táplálékkal történő felvétel, a hormonrendszer, az anyagcserefolyamatok, valamint a természetes kiválasztás/ürülés gondoskodik. Ezek alapján kimondhatjuk, hogy az ásványi anyagok esszenciális tápanyagok, melyek hiánya (akár részleges hiánya is) hiánytüneteket produkál és hiánybetegségeket indukál. A hiány kialakulását – nem megfelelő táplálkozás esetén – az étrend módosításával és étrendiegészítőkkel lehet elkerülni. Jelen dolgozatomban felnőttekre (>18 év) vonatkoztatva a fő kationok – Na^{+}, K^{+}, Ca^{++} és Mg^{++} – élettani szerepével, hiányuk és többletük kialakulásával, valamint ezek elkerülésének lehetőségével és szükségességével foglalkozom, különös tekintettel a magnéziumra.

1. táblázat A fő ásványi anyagok a felnőtt szervezetben

elem	mennyiség (g)*	plazmaszint (mmol/L)**
nátrium	92	135 - 145
kálium	140	3,5 - 5,0
kalcium	1300	2,15 - 2,55
magnézium	25	0,75 - 1,0

Magyarázat:
* mennyiség= a szervezetben fellelhető átlagos mennyiség grammban
** szérumszint = a vérplazmában fellelhető átlagos koncentráció normál (egészséges) tartománya, mmol/L-ben (Canada et al., 2015)

Fontos tudni, hogy egy-egy ásványi anyag mérsékelt hiánya és többlete csak ritkán mutat specifikus tüneteket, éppen ezért észlelésük gyakran problematikus, a lakosság egyes egyedei könnyen kerülnek átmenetileg vagy tartósan rejtett ionhiányba, vagy iontöbbletbe; dinamikus egyensúly jellemzi az élettani helyzetet.

3. A hazai epidemiológiai adatok és jelentőségük

A nemzetközi szakirodalom azt mutatja, hogy a világon mindenhol találkozni ionhiánnyal. Ennek hozzávetőleges gyakoriságát a **2. táblázat** mutatja be. Ebből kitűnik, hogy a kor előre haladtával általában emelkedik a hipomineralémia gyakorisága, s a kórházi ellátás során viszont egy már megbomlott egészségi állapot miatt nő meg az alacsonyabb ionkoncentrációt mutató esetek száma.

2. táblázat A hipomineralémia gyakorisága a nemzetközi szakirodalom alapján*

a) kor szerint

elem	65 év alatt	65 év fölött
nátrium	4%	25%
kálium	14%	2%
kalcium	28%	61%
magnézium	2%	15%

b) a vizsgált populáció szerint

elem	lakossági	kórházi
nátrium	4%	9% (30-40%)
kálium	14%	18% (15-20%)
kalcium	1%	28% (18-85%)
magnézium	2%	20% (7-47%)

*A táblázat adatait a szerző 38 releváns publikáció adatainak felhasználásával állított össze, a zárójeles adatok az ASPEN (American Society of Parenteral and Enteral Nutrition) kézikönyvéből származnak (Canada et al., 2015).

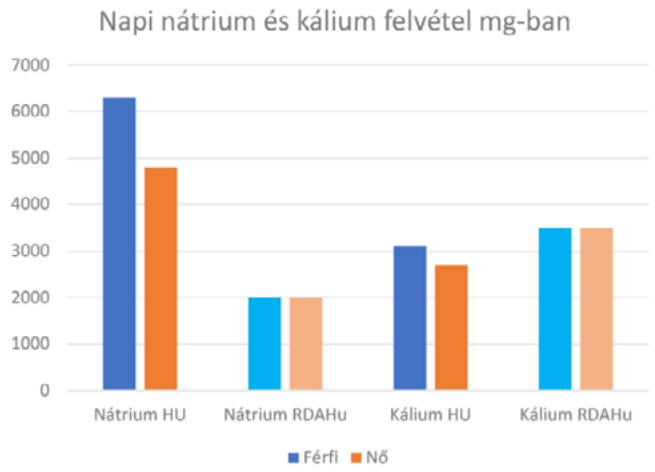
Most azonban koncentráljunk az egészséges, munkakorú lakosságra. Optimális esetben ezek az emberek ásványi anyag ellátottsága a normálértéken belül van, de a valós életben, mint azt a 2. táblázat is mutatja, egy kis százalékban alatta marad a kívánatosnak. Mi lehet ennek az oka? Talán fel nem fedezett betegség korai szakaszában vannak, vagy egyszerűen kevesebb ásványi anyagot vesznek fel a táplálkozásukkal. Ez utóbbit valószínűsíti számos felmérés, pl. az NHANES vizsgálat, mely szerint az amerikaiaknak csak 3%-a veszi fel az adekvát kálium-mennyiséget természetes élelmiszerekből, a hiányzót dúsított élelmiszerből vagy étrend-kiegészítőkből pótolják, ha pótolják (Fulgoni III, V.L., 2011). Ha a hazai adatokat nézzük, a 2019-es OTÁP (Országos Táplálkozási és Tápláltsági Állapot Vizsgálatok) felmérésre (OTÁP, 2019) támaszkodhatunk, mely érdekes adatokat tartalmaz. Ezek az adatok és a bemutatott diagrammok a hazai felnőtt populáció élelmiszerrel felvett ásványi anyagok mennyiségét, s egyben egymáshoz viszonyított mennyiségét mutatják. Az ábrák helyes élettani értelmezéséhez ismernünk kell, hogy a szervezetben nem csak az ionkoncentráció állandó, de az ionok egymáshoz viszonyított aránya is sarkalatos kérdés. Példaként vegyük a nátrium és kálium viszonyát. Az első kation un. extracelluláris kation, az utóbbi intracelluláris, azaz mennyiségük döntő többsége sejten kívül ill. belül található. Az arány állandóságáról un. membrán-transzporterek gondoskodnak, esetünkben a Na^+, K^+-ATPase enzim biztosítja a sejtmembrán elektrokémiai potenciálját, tehát a nátrium-iont sejten kívülre, a káliumot sejten belülre pumpálja, így biztosítva az élettani konstans ionkoncentrációt (Fedosova et al., 2021). Hasonló ion-párt képez a kalcium és a magnézium is. Ez utóbbi két kation pl. az idegsejtek jelátvitelért felelős granulumaiban (pl. gliagrana) találhatók, melyek a membránjukban fellelhető Ca^{++}-ATPase és Mg^{++}-ATPase hatására maradnak az idegsejtek membránjának külső vagy belső oldalán, s váltanak ki akciós potenciált, ha ez az arány valamilyen inger vagy diszfunkció miatt megváltozik (Maier et al., 2023). Tehát az abszolút értelemben vett mennyiség mellett a helyes arányok fenntartása is a szervezet egészséges működésének feltétele.

Ennek kapcsán tekintsük át a jelzett kation-szintek hazai epidemiológiai jellemzőit a hazai és nemzetközi ajánlások tükrében. Előre kell bocsátanunk, hogy a napi javasolt ásványi anyag felvételben a különböző hatóságok és intézmények eltérő mennyiségeket állapítanak meg, ezért az **3. táblázatban** mind a hazai, mind az európai (EFSA = European Food Safety Authority, valamint az Európai Parlament és Tanács [NRV adatok]), mind pedig egy USA-ban vezető egészségügyi intézménynek, a Harvard egyetemnek az adatsorait bemutatom.

3. táblázat A felnőtteknek javasolt napi beviteli értékek, milligrammban

elem	AI*	RDAHu**	Harvard***	NRV****
nátrium	2000	2000	1500	nincs
kálium	3500	3500	4700	2000
kalcium	750/950	800	1000/1200	800
magnézium	350/300	300	420	375

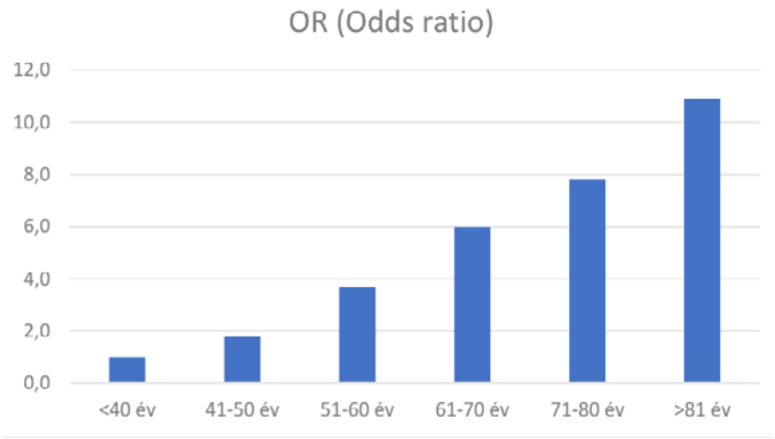
* AI = EFSA Adequate Intake = egészséges egyén napi bevitt mennyisége, milligrammban (ffi/nő)
**RDAHu = a Magyar Élelmiszerkönyv 1-1-90/496 sz. (2002) melléklete szerint javasolt napi bevitel
***Harvard = a Harvard Medical School, az USA egyik legnevesebb orvosi egyetemének ajánlása
****NRV = az Európai Unió 1169/2011/EU rendelete szerinti napi beviteli referenciaérték



1. ábra A hazai tényleges (erősebb színek) és javasolt (halványabb színek) napi nátrium és kálium ionbevitel

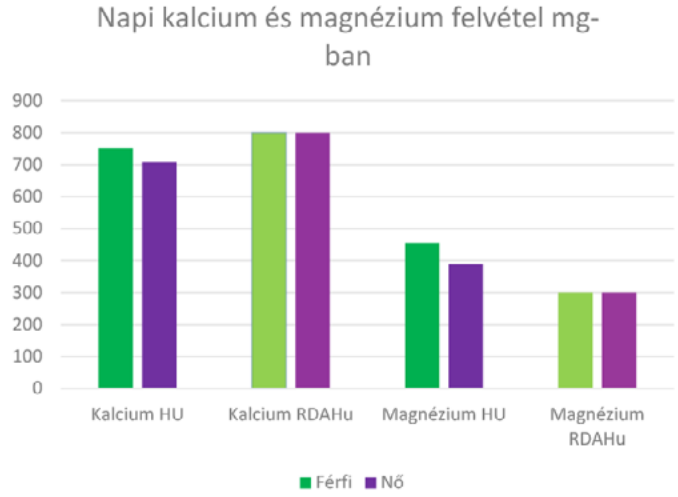
Ha az OTÁP felmérésének eredményeit a hazai ajánláshoz viszonyítjuk, az **1. és 3. ábrák** szerinti arányokat látjuk.

Az **1. ábrából** kiolvashatjuk, hogy Magyarországon a nátriumból gyakorlatilag nincs hiány. A jelentős – döntően konyhasóból – felvett Na^+ nyomán azonban nagy a kockázat a többletre. Ez hipernatrémia révén fokozott folyadékretenciót, ezzel együtt, már gyermekkortól kezdve fokozza – többek között – a hipertónia kifejlődésének valószínűségét. A korfüggő élettani-kórélettani változások révén ez különösen az időseket érinti, melyet a **2. ábra** mutat. Noha időseknek a hiponatrémia is veszélyt jelent (Ganguli et al., 2015], a magas nátrium-szint, mely a védőmechanizmusok korral arányos csökkenéséből következik, emeli az idősek morbiditását és mortalitását egyaránt (Brennan et al., 2021).



2. ábra Közepesen súlyos hipernatrémia kialakulásának esélye a kor függvényében (Upadhyay et al., 2006) adatai alapján

Ezzel szemben – ugyancsak az **1. ábrán** látható – a kálium mindennapos felvétele étkezésekből alatta marad a kívánatosnak. Ez a megfigyelés összecseng Sun és munkatársainak 2021-es, USA-beli felmérésével, mely egyértelműen kimutatja az ottani lakosság évről évre fokozódó kálium-felvételi deficitjét, s amit ők is a táplálkozás (ti. a feldolgozott élelmiszerek nagyobb arányú fogyasztása) megváltozásával magyaráz (Sun, H. et al., 2021). Ez hipokalémia formájában okozhat panaszokat, jellemzően izomgörcsök, szívritmus zavar, alacsony vérnyomás, gyengeség és fokozott szomjúság érzet formájában. Idősek szívműködését ez is jelentősebben megterheli, és következményei révén növeli a kórházi költségeket, továbbá fokozza az összmortalitást (Bardak et al., 2017). További veszély, hogy a hipokalémiás betegek elesése kétszer gyakoribb, mint a normokalémiásoké (Tachi, T. et al., 2015). Feltételezésem szerint ennek az ionnak a pótlásával azonban a hazai lakosság nem igazán foglalkozik, vagy „félrediagnosztizálja", és pl. az éjszakai alsóvégtagi izomgörcsöket magnézium-hiánynak véli, s ezért szedi a magnézium-tartalmú étrend-kiegészítőt.



3. ábra A hazai tényleges (erősebb színek) és javasolt (halványabb színek) napi kalcium és magnézium ionbevitel

A **3. ábra** mutatja a hazai lakosság kalcium és magnézium ellátottságát. Mint látható, a kalcium bevitel elmarad, a magnézium felvétel pedig meghaladja az ajánlott értékeket. Ez több okból is elgondolkodtató. Közvetlenül a magnézium-többlet nem okoz toxikológiai problémát, bár vannak erre is példák: negatív inotróp és kronotróp hatása révén rontja a szívelégtelenséget, vagy provokálhat paralitikus ileust (Eiraku, K.,2022,

Aydin, K., 2020). A magnézium azonban elsősorban a kalciummal áll párban, így – ismét csak a felmérésre hivatkozva – megállapíthatjuk, hogy itt kalcium pótlásra volna szükség a fiziológiás arány fenntartására, a magnézium pótlás viszont indokolatlan, ui. a lakosság a napi táplálkozással, ha az vegyes és változatos étrendből áll, minden külön beavatkozás nélkül felveszi azt a magnézium-mennyiséget, mely az egészséges ionegyensúly fenntartásához szükséges. Nem így a kalcium esetében, ahol a napi élelmezésből fakadó felvétel elmarad a hazai és európai elvárástól, még inkább a Harvard ajánlásától. A felmérésből következő tartós ionbevitel felboríthatja a Ca^{++}/Mg^{++} arányt, és ez nemkívánt hatásokat eredményezhet (Télessy, 2024). Itt azt is meg kell említenünk, hogy ezeknek az ionoknak a felvételét és hasznosulását számos más paraméter is befolyásolja, így pl. a kalcium és a magnézium azonos transzportereken keresztül szívódik fel a bélben, tehát ha lényeges túlsúlyban van egyik a másikkal szemben, akkor egymás felszívódását ronthatják a felszívódásért felelős transzporterért folytatott kompetíció miatt. (Éppen ezért, ha indokolt a Mg-pótlás, azt naponta gyakran, kis adagokban célszerű elvégezni, nem napi egy nagy adag formájában!) Az OTÁP felmérés során felfedett többlet-magnézium felvétel csak kis mértékben tehető felelőssé a lakosság kalcium-hiányos állapotáért, de ha emellett még külön Mg-pótlás is történik, az nagy valószínűséggel hozzájárulhat a megfigyelt hipokalcémiához. A kalciumhiány ugyancsak komoly figyelmet érdemel, hiszen ez az oszteoporózis és a következményes csonttörések hazai előfordulását csak fokozza, akárcsak hipomagnezémia és az – itt nem tárgyalt – D- és K-vitamin hiány is (Capozzi et al., 2020).

Az ásványi sókat tartalmazó élelmiszerek és étrend-kiegészítők helyzetképe

Az ásványi sókat tartalmazó étrend-kiegészítők forgalmát tekintve úgy tűnik, hazánk lakossága számos hiánybetegségben szenved. Az OTÁP adatok is az étrend-kiegészítők forgalmának folyamatos emelkedését mutatják (OTÁP, 2019). Ha a hiány valós lenne és ezt a lakosság észleli, majd ezért fogyaszt igényeinek megfelelő étrend-kiegészítőket, még örülhetünk is ennek. Aggasztóbb azonban az, hogy valójában kevés az iondiagnosztikán nyugvó ionpótlás, hiszen a rutin laborvizsgálatokba (un. metabolikus panel) a keringő ionoknak csak egy része tartozik bele, a Mg^{++} például nem. Rutin laborvizsgálatra is a lakosság nagy részénél csak valamilyen betegség kivizsgálása során kerül sor. További megfontolásra érdemes az a tény, hogy a laborértékek csak a vérben mért ionkoncentrációkat mutatják, ami nem mindig demonstrálja a sejtszintű ion-státuszt. A vérben ugyanis a szervezetben lévő magnéziumnak csak 1%-a, a szérumban kevesebb, mint 0,3%-a van! Az is figyelemre méltó, hogy ha valaki csak esetenként vesz be magnézium-tartalmú gyógyszert és étrend-kiegészítőt, az a vérszintet átmenetileg megemeli, de mélyreható, szisztémás Mg-telítettséget nem eredményez, tehát a sejtek magnézium-koncentrációját nem fogja javítani. A magnéziummal való feltöltöttség hiteles vizsgálata az ürítés mérésével valósítható meg: ha a bevett vagy beadott magnézium-mennyiség 60-70%-a 24 óra alatt vizelettel ürül, akkor az magnézium-telítettségre utal (Bajnok, 2013). Ugyancsak elgondolkodtató az, hogy a NÉBIH felmérése szerint a lakosságnak kb. fele kizárólag a gyártók/forgalmazók tanácsaira támaszkodik, ha úgy véli: neki étrend-kiegészítőre van szüksége (NÉBIH, 2021).

Az élelmiszerekkel felvehető ásványi anyagok mennyiségének változásával sokat foglalkozik a sajtó, de szakmailag megalapozott érveket keveset találunk. Az biztos, hogy a táplálkozási szokások változása – pl. a feldolgozott vagy erősen feldolgozott élelmiszerek arányának megnövekedése a mindennapi táplálkozásban – befolyásolja a szervezetbe bejutó ásványi anyagok mennyiségét, akárcsak pl. a vitaminokét, nyomelemekét. Ismert, hogy pl. a fehér (hántolt) rizs több, mint 4,5x kevesebb magnéziumot és majd 3x kevesebb káliumot tartalmaz, mint a barna rizs (Farthing, 2020). De az idő előre haladtával maguk a zöldségek és gyümölcsök beltartalma (itt: ásványi anyag tartalma) is változott, ezt a **4. táblázat** demonstrálja. A táblázatban meghatározott gyümölcsök és zöldségek ásványianyag-tartalmát a Pharmakonzern Geigy 1985-ben, és egy Karlsruhei élelmiszer laboratórium 2002-ben mérte (Gräber, 2022).

4. táblázat Zöldségek és gyümölcsök beltartalmának változása 1985 és 2002 között (mg/100g)

Alapanyag	Ionmeghat.	1985	2002
Brokkoli	Ca	103	28
	Mg	24	11
Fejtett bab	Ca	56	22
	Mg	26	18
Burgonya	Ca	14	3
	Mg	27	14
Banán	Ca	8	7
	Mg	31	24
Eper	Ca	21	12

A fentiekhez hasonló (de 1991 – 2022 között mért) csökkenésről számolt be a közelmúltban többek között egy ausztrál kutatócsoport is (Rangan et al., 2022). A különbségek jelentősek, még akkor is, ha figyelembe

vesszük az esetleges fajtabeli különbségeket. A jószándékú fogyasztó erről alig értesül, s ha valahogyan mégis, hát sokat nem tud ellene tenni. Az ásványi anyag vesztésnek számos oka lehet, ezt itt nem kívánom kibontani. Azt azonban megállapíthatjuk, hogy egyes esetekben valóban indokolt lehet az élelmiszerek dúsítása, illetve meghatározott egyéneknél a mesterséges ionpótlás.

5. A magnézium szerepéről és pótlásáról, röviden

Mivel hazánkban a magnézium-tartalmú étrend-kiegészítők forgalma a legnagyobb az összes ásványi anyagot tartalmazó készítmények közül, indokolt egy rövid fejezetet szentelni arra, hogy ennek következményeit megértsük.

A magnézium mintegy 600 enzim kofaktora, főként azoké, melyek az energiatermelésben és -felhasználásban szerepet játszanak, valamint amelyek más ionok transzportjában részt vesznek (Adamako et al., 2024). Nem elhanyagolható a szerepe a genom fenntartásában (DNS javítás, replikáció, transzkripció, transzláció), továbbá struktúra-stabilizáló funkciója van a nukleinsavak és fehérjék esetében. Ezek mellett lényeges kation az elektrofiziológiai eseményekben, ahol mind a kalcium-, mind a kálium-csatornák megfelelő működése Mg^{++}-függő, és a kalcium-ionok kalmodulinhoz, troponin C-hez, valamint parvalbuminhoz kötődéséhez is magnézium kell (Plichova et al., 2017). Nem véletlen tehát, hogy a magnéziumhiányt kardiovaszkuláris betegségek, kettes típusú diabétesz, oszteoporózis, mentális betegségek és még egyéb kórképek kiváltójaként vagy állapot-rontójaként emlegetik. Ez a felsorolás is jelzi, hogy komoly kapcsolatrendszernek/hálózatnak része a magnézium. Azt is meg kell említeni, hogy a már korábban is jelzett ionegyensúlyok révén a hipomagnezémia előbb-utóbb hipokalémiát és hipokalcémiát is eredményez, ezeken keresztül pedig a hormonrendszert (paratireoid és antidiuretikus hormonok ill. inzulin) is befolyásolja (Ehrenpreis et al., 2021). Ha valakinek valóban alacsony a magnézium szintje, akkor azt rendezni kell. Ennek elsődleges lépése a hiány okának kiderítése, s ha ez kórélettani alapú (pl. a vese kóros Mg-vesztése), akkor azt kell korrigálni. Ha nem ez a probléma vagy nem lehet rövid időn belül helyreállítani a kóros szervműködést, akkor pótolni kell a magnéziumot annak érdekében, hogy a jelzett Mg-függő élettani funkciók megfelelően működjenek.

Magnézium pótlásra vannak gyógyszerek és étrend-kiegészítők. Mindkettő alkalmas lehet a hiány rendezésére, de míg a gyógyszerek esetében tudható az, hogy a hatóanyag a deklarált mennyiségben van jelen, s annak biológiai hasznosulása bizonyított, addig az étrend-kiegészítők esetében nincs előírva kötelező ellenőrzés, így ásványi anyagok esetében a csomagoláson deklarált mennyiségtől +45/- 20%-ban eltérhet a gyártó, sem a hatóanyag felszabadulás (pl. tabletta szétesés a gyomorban), sem a felszívódás mértéke, tehát a hasznosulás nem ismert. Ennek a Mg-tartalmú étrend-kiegészítők esetében azért van jelentősége, mert, mint azt fent jeleztem, sokan indokolatlanul vagy tévedésből szednek ilyen étrend-kiegészítőt, s az így kialakuló Mg-többlet (=relatív hipermagnezémia) káros lehet a szervezetre. Az eddigi vizsgálatok szerint az egészséges Ca:Mg arány 2,5-3 között van. Ha ettől akár lefelé, akár fölfelé eltér az arány, az kódos következményekkel járhat.

Dai és munkatársai közel 75 ezer kínai hölgy és 61.500 kínai férfi vizsgálata nyomán megállapította, hogy az USA-ban végzett vizsgálatokkal szemben a magas magnézium bevitel (tehát alacsony Ca-Mg arány) fokozta az össz-halálozás kockázatát (Dai et al., 2012).

Ezzel szemben a túl magas Ca:Mg arány sem jó; DeLuccia és mtsai 56 egyénre kiterjedő vizsgálata szerint a Ca:Mg arány abban a felnőtt populációban 3,37 (18-29 évesek) és 3.58 (30-39 évesek) között mozgott, és a magas arány szignifikánsan összefüggött a gyulladásos paraméterek (pl. IL-6) emelkedett vérszintjével (DeLuccia et al., 2019). Egy másik vizsgálat arra mutat rá, hogy az 1977-ben mért átlagosan 2,3-2,9 közötti Ca:Mg arány 2007-2008-ra 2,9-3,5 közötti szintre emelkedett, s ez korrelációt mutatott mind a 2. típusú diabetes mellitus, mind a vastagbél rák incidenciájának és prevalenciájának emelkedésével (Rosanoff, 2010).

Az NHANES vizsgálat (USA) azt mutatta, hogy 2007-től kezdve a normál étkezéssel is túl magas Ca:Mg arány a túlzott Ca-kiegészítők használata miatt tovább nőtt, s ha ez az arány tartósan 3 fölött van (= relatív Mg hiány), akkor az egyes rákfajták kialakulásának kockázatát hordozzák (Costello et al., 2021). Hazánkban épp a magnézium pótlás van túlsúlyban. Ezért oda kell figyelni arra is, hogy ha a Ca:Mg arány 1,7 alá esik, tehát erős relatív túlsúlyba kerül a Mg, akkor, úgy tűnik, az ismét csak a fokozott kardiovaszkuláris kockázat és rákos megbetegedések emelkedése irányába tolja el a mérleg nyelvét (Li et al., 2020).

6. Megbeszélés

A hazai felmérés nem támasztja alá azt a feltételezést, hogy a magyar emberek általános ásványianyag-hiányban szenvednének. Sokkal inkább az állapítható meg, hogy egyes kationokból (Na^{+}, Mg^{++}) a kelleténél többet, másokból (Ca^{++}, K^{+}) kevesebbet visznek be a napi étkezéssel szervezetükbe az optimálisnál. Ezt, talán a szabad hozzáférés, valamint a hirdetések hatására is, a magyar lakosok jelentős mennyiségű étrend-kiegészítővel igyekeznek pótolni, pedig a hiánynak megfelelően kiválasztott, az adott ionban gazdag élelmiszerek (gyümölcsök, zöldségek) fokozott fogyasztása lenne az ideális megoldás. A „tablettás” ionpótlás csak elvétve alapul laboratóriumi vagy más orvosi vizsgálatokon, így ez a szokás ártalmas ioneltolódásokhoz vezethet, ami fokozott kockázatot jelent bármilyen megbetegedés kialakulására vagy romlására.

Az Európai Parlament és Tanács irányelvét követve a 37/2004. (IV. 26.) ESZCSM rendeletével Magyarország is feloldotta az étrend-kiegészítők kötelező engedélyezését, s ezzel összefüggésben a forgalomba hozatalukat megelőző vizsgálatát. Ezzel együtt járt az is, hogy a fogyasztók csak formális információhoz juthatnak a tényleges hatóanyag tartalomról, várható felszívódásukról és hasznosulásukról. Ezt azonban a piac nem veszélynek, hanem a szabadság megnyilvánulásának vette, s az étrend-kiegészítők száma és forgalma exponenciális emelkedésnek indult. Sajnos, az e termékkörre vonatkozó hirdetések is számos tekintetben felelőtlen fogyasztásra ösztönöznek, még olyan célcsoportban is, mint a sportolók, akik döntően megfontoltan egészségtudatos vásárlóknak számítanak (Szűcs et al.,2020). A hivatkozott szerzők felméréséből kitűnik, hogy a vitamin és ásványi anyagok csoportban legmagasabb a naponta, vagy naponta többször fogyasztók aránya, tehát itt a bevitt „hatóanyag" túladagolása nem zárható ki. Ez különösen azért elgondolkodtató, mert, mint arra korábban rámutattam, a termékről az információt főleg a gyártói tájékoztatásból szerzik be, ami ebben a termékkategóriában érthetően elfogult. A magnézium általános hiánya hazánkban az étkezési szokások és az OTÁP felmérésének ismeretében nem támasztható alá. Még akkor sem, ha ismert, hogy az idősek általános táplálékfelvétele elmarad a kívánatostól, vagy a vegyes étrenddel is kevesebb ásványi anyaghoz jutunk, mint pár évtizeddel ezelőtt, továbbá vannak olyan körülmények (vesebetegség, hányás-hasmenés, gyógyszerek) melyek fokozzák a magnézium ürítését. És az is ismert, hogy a feldolgozott/ fokozottan feldolgozott élelmiszerek jelentősen lecsökkentik az adott étel ásványi anyag tartalmát.

Ahogy általánosan ismert, hogy egészségünk védelmébe a konyhasó (=NaCl) bevitelét csökkentenünk kell, a jövőben arra kellene hangsúlyt fektetni, hogy a Mg-tartalmú gyógyszerek és étrend-kiegészítők használatát is célszerű racionalizálni. Ismét csak a NÉBIH felmérésre hivatkozva idézem: „….az alapvető információkkal, a termékkör sajátosságaival már nincsenek teljesen tisztában a vásárlók" (NÉBIH, 2021). A kálium-tartalmú készítmények használatát pedig, ha az nem vényköteles készítményekre vonatkozik, népszerűsíteni, ha pedig orvosilag indokolt (pl. K-ürítő vízhajtót kap a beteg), a vényköteles gyógyszerek felírását, ill. a felírt kálium-pótló gyógyszer rendszeres bevételét kellene ösztönözni.

Ami a magnézium-tartalmú gyógyszerek és étrend-kiegészítők szedését illeti, tudnunk kell, hogy azt csak alapos indokkal tegyük, hiszen, mint azt fent bemutattam, az ionok egymással konstans élettani arányban állnak, s egy-egy elem túlsúlya ronthat a homeosztázison. A régóta ismert, leggyakoribb példa erre a magas vérnyomás, melynek szabályozásában mind a négy fent említett ion kulcsszerepet játszik (Houston et al., 2008).

7. Összegzés és következtetések

Noha az ásványi anyagok hiánya vagy relatív hiánya csak kevés panaszt okoz az embereknek, ismerve széles körű élettani szerepüket, nagy valószínűséggel kicsit ez is hozzájárulhat a hazai lakosság rossz általános egészségi állapotához. Dolgozatomban arra igyekeztem rámutatni, hogy szemben számos nemzetközi felméréssel hazánk lakosságában a relatív magnézium-többlet és a relatív kálium hiány a jellemző, ezért az ásványi anyagok pótlása terén a hazai helyzethez adaptált tájékoztatásra van szükség. A változatos és sok gyümölcsöt-zöldséget magába foglaló egészséges táplálkozás ösztönzése így e téren is hozzájárulhat a lakosság egészségének javításához. Ha pedig bárkinek ásványi anyag hiánya jelentkezik és gyógyszerre vagy étrend-kiegészítőre van szüksége, azt megfontoltan, lehetőleg orvosi-gyógyszerészi konzultációt követően szerezze be, s azt megfelelő mennyiségben és csak a szükséges ideig alkalmazza.

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Hypo- and hypermagnesemia of the Hungarian population

Keywords: hyponatremia, hypokalemia, hypocalcemia, hypomagnesemia, dietary supplement

1. Abstract

Reviewing the international scientific literature, it seems that in a large part of the world hypomineralemia is present. Based on the sales figures of dietary supplements in Hungary, one can assume that Hungarians suffer from severe hypomineralemia. Epidemiological data show, however, that the Hungarian population in general, does not suffer from hypomineralemia. Interestingly, in contrast to the western pattern, in Hungary lower potassium and calcium levels are typical and instead of hypomagnesemia, mild hypermagnesemia is common. Thus, in this country supplementation of individual deficiency as well as increased support in case of hypermineralemia is recommended. These targets could be reached by preventive interventions, such as with proper selection of daily consumed food and nutrients. Improper consumption of dietary supplements causes harm therefore ion-supplementation should be done carefully and must be based on laboratory verified deficiency.

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2. Introduction

Hypo- and hypermineralemia means that the patient's blood parameters of minerals are out of the normal range (**Table 1**.). Minerals are indispensable components of the body, they take out ca. 6% of body weight. These elements are present in soluble form as in electrolytes and participate in the acid-base homeostasis and ion-regulation but in bound form they participate in almost all biochemical reactions. Their quantity and interrelations are standard within a narrow range, this is ensured by food uptake and regulated by hormone systems, metabolic processes, as well as by excretion. Based on these, we can state that minerals are essential nutrients and their deficit (even partial deficit), as well as excess, results in complaints and deficiency symptoms. Development of deficiencies can be avoided with consumption of diverse diet and, if necessary, by taking medicines and/or dietary supplements. In our present study we aim to present physiological impact, development of deficits and excess as well as the avoidability of such deviations of the main cations Na^{+}, K^{+}, Ca^{++} and Mg^{++}, with special attention tomagnesium.

Table 1. Main minerals in the adult body

Minerals	Quantity*	Plasma levels**
sodium	92 g	136 – 144 mmol/L
potassium	140 g	3,7 - 5,1 mmol/L
calcium	1300 g	2,2 - 2,6 mmol/L
magnesium	25 g	0,7 - 1,2 mmol/L

Explanation:

* Quantity = Total average amount in the body (in grams)

** Plasma levels = average mineral content in plasma: the normal range in mmol/L (Canada et al., 2015)

It is important to mention that signs and symptoms of mild deficiency or excess of these elements are scarcely specific therefore diagnosis of such ailment should based on laboratory blood tests. Consequently hidden hypo- or hypermineralemia can often be transiently present in the population even if the dynamic balance is within the norm.

3. The applicable epidemiological data and their impact

Survey of the international scientific literature shows that one meets with hypomineralemia all over the world. Approximated incidence of hypomineralemias is presented in **Table 2**. It is visible that incidence increases by ageing and that higher values are found due to the disabled (hospitalized) patients displaying less compensatory capacities.

Table 2. Incidence of hypomineralemia (according to international literature)*

a) according to age

Minerals	Under 65 years	Above 65 years
sodium	4%	25%
potassium	14%	2%
calcium	28%	61%
magnesium	2%	15%

b) according to population

Minerals	Ambulatory	Hospital
sodium	4%	9% (30-40%)
potassium	14%	18% (15-20%)
calcium	1%	28% (18-85%)
magnesium	2%	20% (7-47%)

* Presented data were calculated by the author based on 38 different publications. The data in parentheses originate from the handbook of ASPEN (American Society of Parenteral and Enteral Nutrition (Canada et al., 2015))

Let's focus on the 'healthy' population. Their supply of minerals is, in general, within the normal range but, as seen in **Table 2**, certain proportions of them lie under the normal values. What is the reason for deviations like these? Maybe, in some cases unrevealed disease is in the background, but majority of such ion-deviations are attributed to undernutrition of these minerals. The latter is affirmed by the NHANES study in the USA (Fulgoni

III, V.L., 2011). The data of the Hungarian National OTÁP2019 Survey and the 'Nutritional habits of Hungarian older adults' study corroborate the figures as well [OTÁP2019, Zámbó et al. 2021, Soós et al. 2024].

Should we look at the data of the National OTÁP2019 Survey, we may observe some interesting facts. All figures originate from healthy adults taking nutrients, including minerals, from regular daily meals only and display the quantitative uptake of minerals and their relations to each other. In order to understand the figures, we should know that not only ion-concentration is important in evaluation of the actual health situation but the balance of ions as well. For example take the relation of sodium to potassium. The former cation is an extracellular ion and the other is an intracellular one, i.e. most of the ions are outside the cells and, in the cells, respectively. The constant proportion is ensured by membrane-transporters, chiefly the enzyme Na^+, K^+-ATPase and this creates the electrochemical potential of the cell membrane. It means, the above mentioned enzyme pumps Na^+ out and K^+ into the cell (Fedosova et al. 2021). Similar ion-pairs are Ca^{++} and Mg^{++}. These bivalent cations are responsible for the signal transmission of neural cells via the membrane-enzymes Ca^{++}-ATP-ase and Mg^{++}-ATPse, respectively. For any stimulus, the ratio of Ca^{++} and Mg^{++} between the two sides of the cell membrane changes and results in action potential (Maier et al., 2023). Thus, apart from the absolute quantity of the ions, their constant ratios are of importance in maintaining the healthy function of the body.

Now, let's review the epidemiologic characters of the mentioned cations on the local and international level. It should be anticipated that for the recommended daily allowance (RDA) of this particulate case different authorities and institutions set different levels, thus in **Table 3**. we listed the RDA-s of Hungarian (RDAHu) and European (RDA) Authorities as well the recommendations of one of the leading prestigious healthcare institutions, Harvard University (Harvard1, Harvard 2 and Harvard3).

Table 3. Recommended daily allowance in milligramms

Ions	AI*	RDAHu**	Harvard***	NRV****
sodium	2000	2000	1500	none
potassium	3500	3500	4700	2000
calcium	750/950	800	1000/1200	800
magnesium	350/300	300	420	375

* AI = EFSA Adequate Intake = daily intake of a healthy person per day in milligrams (male/female)

**RDAHu = Hungarian daily recommendation according to the Hungarian Food Book [Codex Alimentarius Hungaricus] (Magyar Élelmiszerkönyv 1-1-90/496 sz. (2002) melléklete)

***Harvard = recommendation of the Harvard Medical School, USA

****NRV = Daily reference value according to the Regulation (EU) No 1169/2011 of the European Parliament and of the Council

Should we compare the OTÁP2019 data to the Hungarian RDAs, we see the landscape of **Figure 1** and **Figure 3**.

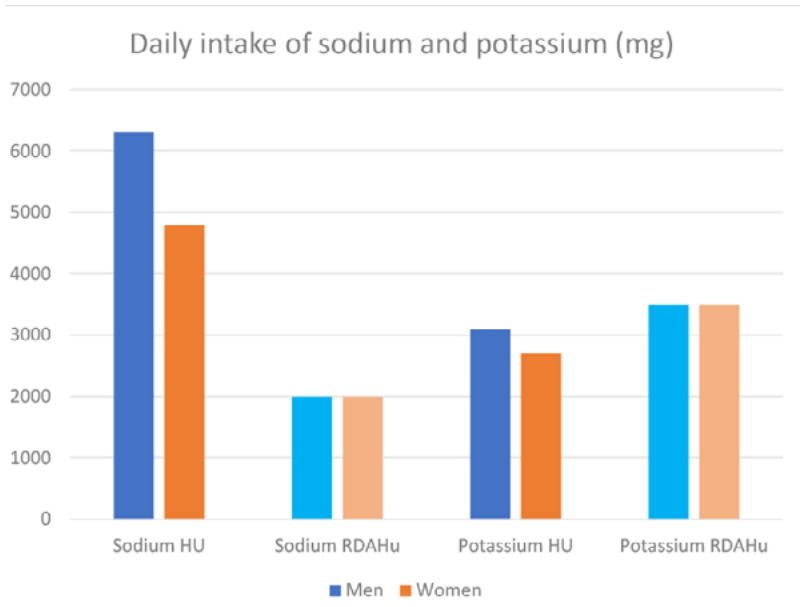

Figure 1. Measured (dark color) and recommended (light color) daily intake of sodium and potassium

From **Fig. 1.** we can read, that in Hungary there is no lack of sodium in the young population but the Na^+ uptake – predominantly resulting from the daily diet – is much higher than recommended. A similar finding is seen in the study of Sarkadi-Nagy (Sarkadi-Nagy et al, 2021). This leads to increased fluid-retention and a concomitantly high risk for development of hypertension. Astonishingly, it is more common in the elderly, as demonstrated in **Figure 2**. due to the age-dependent physiological and pathophysiological changes. While hyponatremia is dangerous in the elderly (Ganguli et al., 2015), high sodium-levels, which are a consequence of e.g. inadequate fluid intake or kidney disease, due to the diminished compensatory mechanisms, more frequently increase the morbidity and mortality of the elderly (Shah et al., 2014).

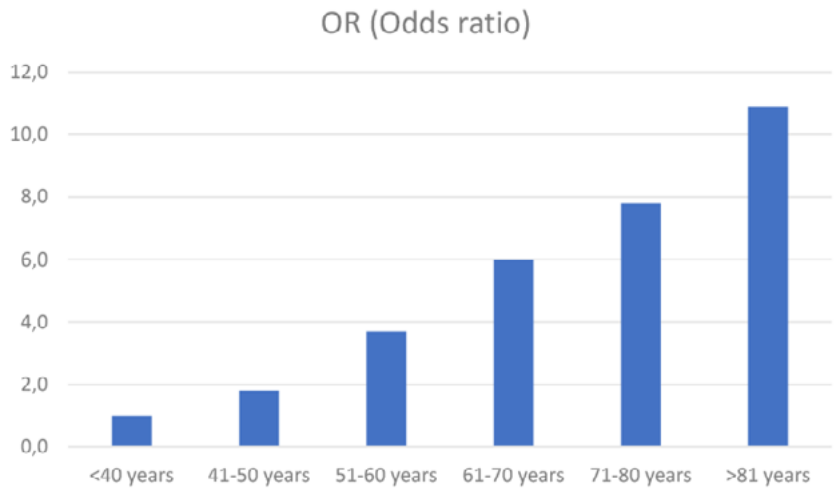

Figure 2. The odds for medium severe hypernatremia according to years of age. (Based on data of Upahyay et al. 2006)

In contrast, as also demonstrated in **Figure 1**., daily uptake of potassium from daily meals lags behind the recommendations. This is in corcondance with the survey of Sun et al (2021) which demonstrated that the USA population takes up less and less potassium from their daily food and this is attributed to changes in dietary habits, i.e. more processed foods are consumed (Sun, H. et al., 2021). This may cause symptoms in the form of hypokalaemia, characteristically in the form of muscle cramps, cardiac arrhythmias, low blood pressure, weaknes, and increased thirst. In the elderly, cardiac functions are overloaded which elevate hospitalization costs and increase mortality figures (Bardak et al., 2017). Moreover, the fall of hypokalemic patients is doubly as frequent as in normokalemic patients (Tachi, T. et al., 2015). Supplementation of these ions are, however not a priority for Hungarians, or – according to my suspicion – due to misdiagnosis they ascribe night cramps of the lower limbs/calf to magnesium deficiency and therefore take magnesium containing dietary supplements without medical consultation.

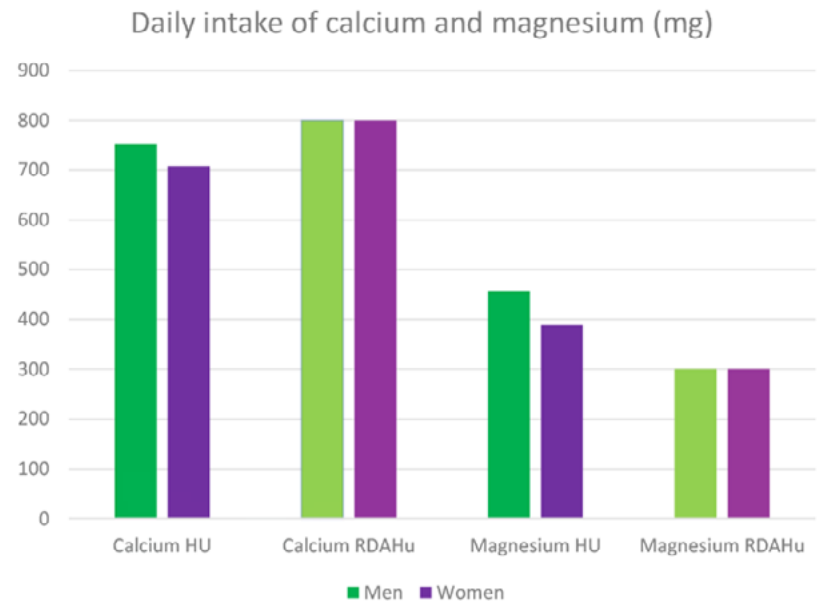

Fig. 3. The calcium and magnesium provision of the Hungarian population (measured values are in dark columns, recommended values in light columns)

Figure 3. presents the provision of local population with calcium and magnesium in contrast to the recommended values. As visible, calcium intake is less than needed, conversely, natural magnesium intake is more than recommended. This is worrisome! Direct hypermagnesemia usually does not results in toxicological consequences, however, there are some examples for this as well. Its negative ionotropic and chronotropic effect worsens cardiac insufficiency and may provoke paralytic ileus, too (Eiraku, K.,2022, Aydin, K., 2020). Magnesium stands in a pair with calcium, thus in order to maintain healthy ion-relations calcium intake should be increased and magnesium intake decreased, viz. a population with diverse and healthy diet patterns are able to ensure the uptake of needed amounts of magnesium and will not overintake calcium, which is desirable in order to maintain optimal ion-balance. Not so in the case of calcium where daily uptake from average diet is less than recommended by the local as well as international guidelines. The continuous hiperalimentation with magnesium and hypoalimentation with calcium can alter the Ca^{++}/Mg^{++} intake ratio and this may result in pathophysiological consequences (Dai et al. 2013). Here should be mentioned that absorption and bioavailability of these ions are influenced by several other parameters as well, e.g. the Ca^{++} and the Mg^{++} are absorbed via the same transmembrane transporters in the gut thus the local concentration of one of them alters absorption of the other one due to the competition for the transporters' capacity. Therefore if Mg-supplementation is recommended, it should be done with small amounts but frequently, instead of one big dose per day. On the population level, the moderate overingestion of magnesium is obviously not the reason for hypocalcemia but due to the huge amounts of sales of Mg-containing dietary supplements, in some cases this may contribute to the observed hypocalcemia. The putative hypocalcemia on a population level is worth considering because of the increased risk for osteoporosis and the consequent fractures, as does hypomagnesemia and the resulting deficient vitamin D levels (Capozzi et al., 2020).

4. Present situation of foods and dietary supplements containing minerals

Regarding the sales figures of dietary supplements containing minerals it seems the Hungarian population suffers from several and different deficiency syndromes. The Hungarian survey on consumption of dietary supplements also supported the steady increase in sales figures (OTÁP2019 report). If the deficit were a true deficit and the people realized the imperfect intake of certain minerals and had taken mineral-containing dietary supplements in response, it would be gratifying! The pity is, that there are very few supplementations based on ion-diagnostics.Mineral deficiencies have unspecific symptoms and patients of hidden mineral deficits rarely turn to MDs with these complaints. Moreover, actual laboratory data seldom show alarming signs. In the case of Mg^{++}, just 0.3% of the total magnesium is present in the serum and it does not represent the true intracellular value. Especially if an individual takes dietary supplements only occasionally and the measurement is done within some hours of the Mg^{++} -administration; in this situation serum-Mg levels are much higher than that in other tissues. Reliable measurement of how tissues are loaded with magnesium is the measurement of excretion: if the 60-70% of a certain dose of Mg^{++} was excreted by urine within 24 hours, it alludes to a well-loaded body. Also alarming that ca. half of the population exclusively follows the recommendations of the manufacturers, if dietary supplements are in question (NEBIH, 2021).

Media often deals with changes in the mineral content of the diet but the professional approach is scarce. The fact is, that alterations in eating habits – increase in proportion of processed and ultraprocessed food in the daily meal – influence the total mineral intake as well intake of vitamins and trace elements. It is known that for exampe white rice contains 4.5-times less magnesium and 3-times less potassium, than brown rice (Farthing, 2020). But there are documents that even raw materials (vegetables, fruits) contain less minerals today, than some decades ago. This is presented in **Table 4.** The data originated from the laboratory of Pharmakonzern Geigy from 1985 and the Food Laboratory of the Karlsruhe, Germany, from 2002 (Gräber, 2022).

Table 4. Change in ion content of vegetables and fruits between 1985 and 2002 in mg/100g

Raw material	Ions	1985	2002
Broccoli	Ca	103	28
	Mg	24	11
Beans	Ca	56	22
	Mg	26	18
Potato	Ca	14	3
	Mg	27	14
Banana	Ca	8	7
	Mg	31	24
Strawberry	Ca	21	12

A similar decrease has recently been published by an Australian research group, too (Rangan et al., 2022). Differences are appreciable, even if we take into consideration the accidental change of strains. The population has hardly any information about this, with especially no information on the specific food he/she purchases in the supermarket. The reasons for the loss of content are not to be discussed in this article. However, it can be stated that fortification of certain foods with minerals and vitamins has raison d'étre and, in certain individuals, administration of dietary supplements is also a reasonable assumption.

5. On the physiological role of magnesium and its supplementation

As the sales of magnesium-containing dietary supplements are the highest of all mineral-containing supplements, we are motivated to discuss the situation and the prospective consequences.

Magnesium is a cofactor of ca. 600 enzymes, being chiefly active in energy production and energy utilization, and where iontransports are involved in the biochemical processes (Adamako et al., 2024). Magnesium has a role in the maintenance of the human genome (DNA repair, replication, transcription, translation), further it has a function in structure-stabilization in the case of nucleic acids as well as proteins. This cation is important in electrophysiological processes where the proper function of Ca^{++}- and K^{+}-channels depends on the presence of Mg^{++} (Plichova et al., 2017). Consequently, hypomagnesemia plays a role in the pathophysiology of cardiovascular disease, Type-2-diabetes mellitus, osteoporosis, and mental diseases, etc. All of these underline the necessary presence of magnesium in a complicated physiological-biochemical network. Here should be recalled the impact of ion-balance, viz. hypomagnesemia induces hypokalemia and hypocalcemia and these affect hormonal systems (parathyroid-, antidiuretic system and insulin) as well (Ehrenpreis et al., 2021). If anyone really had low Mg-levels, it should be corrected. The first step in this direction is to explore the reason for the deficit. Should pathophysiological reasons be in the background, it must be treated. If pathophysiological problems were excluded, low intake should be corrected, at first with analysis of the eating habits. For example, in Hungary there is a high rish for non-communicable diseases due to an unhealthy diet on a population level: Hungarians consume less than the EU average of vegetables, fruits, nuts, and whole grain products (Tufts University, 2022).

For supplementation of magnesium there are medicines, nutraceuticals, and dietary supplements available. All of them are suitable, however only medicines guarantee their content and bioavailability due to authorization conditions. According to the EU regulations, dietary supplements containing minerals are subject to food regulations and the specific tolerated manufacturing deviation limits of mineral content ranges from -45 to +25% (Directive, 2002)! Disintegration of tablets, absorption of the content, and bioavailability are not regulated. This has an impact from a patient-safety point of view because, as mentioned above, many Hungarians take magnesium-containig dietary supplements as if they were a part of the daily meal or due to misdiagnosis (leg cramps). Usually, surplus excretes but a regularly overladen Mg-pool may cause pathological deviations in ion-homeostasis. According to the present understanding the healthy Ca^{++}: Mg^{++} ratio is between 2.5 and 3.0. The deviation of this range may result in pathological consequences.

Dai and co-workers assessed nearly 75,000 Chinese females and 61,500 Chinese males and found in contrast to the USA that high intake of magnesium (i.e. low Ca:Mg ratio) resulted in an increase in the risk of total mortality (Dai, 2012).

Then again, neither is too high a ratio of Ca:Mg beneficial: in the study of De Luccia at al. Ca:Mg ratio in 56 adults was 3.37 (18-29 years of age) and 3.58 (30-39 years of age) and this high ratio was in significant correlation with elevated levels of inflammatory parameters (e.g. IL-6) in the blood. (DeLuccia et al., 2019).

Another study points out that in 1977 the measured 2.3 – 2.9 Ca:Mg ratio increased to 2.9 – 3.5 in 2007/2008 and this correlated with an elevated incidence and prevalence of Type-2-diabetes mellitus as well as colon carcer (Rosanoff, 2010).

The NHANES study (USA) shows that from 2007 the Ca:Mg ratio increased due to the excessive use of Ca-containing supplements and if it was above 3.0 (i.e. relative Mg-deficit) the risk fordevelopment of certain types of cancer increased(Costello et al., 2021). In Hungary, it is just the opposite: the Mg-supplementation is in dominance. Thus, if the Ca:Mg ratio falls under 1.7, i.e. the Mg comes to relative excess, the cardiovascular risks and cancer probability increases (Li et al., 2020).

6. Discussion

According to the Hungarian dietary and food survey data Hungarians have no general mineral-deficiency. However, food consumption measurements demonstrate that Hungarians take in less calcium and potassium, but more sodium and magnesium from daily meals, than recommended. These deviations are worsened by voluntary and groundless consumption of magnesium, but non-consumption of K^{+} and Ca^{++} containing, supplements. This can be attributed to advertisements as well as to free access to these products. The best

(ideal) solution would be an altered eating habit: the increased consumption of ion-rich nutrients (vegetables, fruits) and avoiding ultraprocessed food. Unfortunately, supplementation based on medical examination and/or laboratory tests is scarce.

Following the Guideline of the European Parliament Hungarian legislation abolished the former registration process for dietary supplements. This brings about that consumers get formal information only about products. The market regarded this change as the arrival of freedom, not risk and the number as well as consumption of dietary supplements increased dramatically. Regrettably, the advertisements increased exponentially as well and urged people to irresponsible consumption, even consumer groups like athletes who usually are considered more health-conscious customers (Daher et al. 2022). The referred publication also attracted attention to the potential contamination and other risks associated with dietary supplement consumption.

As it is generally accepted, the intake of common salt (NaCl) should be reduced in order to improve health-related quality of life. To target the same goal, in the future Hungary should rationalize the use of drugs and dietary supplements, including magnesium-containing drugs and dietary supplements. This can be achieved via education in schools as well as adult education, and by enabling free consultation with healthcare professionals for the whole population.

7. Summary and conclusions

Based on the population-wide survey of Hungarian ion-status, general deficiencies or excesses can not be determined. Still, inadequate potassium intake and overconsumption of magnesium can be detected in a propertion of the population. The deficit or relative deficit of minerals seldom precipitates symptoms for individuals. However, these deficiencies, due to their complicated role in the maintenance of normal health, may contribute to generally poor health-related figures (Hungary, 2023). The estimation of the individual ion-supply, proper explanations of the signs and symptoms, and further extensive education may lead to a healthy diet and to avoiding erroneous or needless ion-supplementation.

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Comparison of physico-chemical properties of different types of vegetable oils prior to and post deep frying

Keywords: deep frying, oil oxidation and thermal destruction, fatty acid composition, polar compounds, UV-VIS oil spectra, physico-chemical characterization of oils, vegetable oils

1. Abstract

Deep frying is one of the most commonly used methods of food preparation. An essential factor in the frying process is the choice of a suitable oil – it plays a role in the heat transfer and as a product impregnation medium. Repeated use at high temperature leads to a number of reactions of oxidation, polymerization, and thermal destruction, which lead to changes in oils' physical, chemical, nutritional, and sensory properties. Since the changes result from different processes, they cannot be evaluated by a single method. The processes differ in their extent for the different oil types. Therefore, the aim of the present study is to investigate the quality changes in three vegetable oils, namely refined sunflower oil, high oleic acid sunflower oil (HOSO), and rapeseed oil using different physical and physico-chemical methods. General chemical parameters, such as acid value and fatty acid composition were measured by standard methods, namely titrimetry and gas chromatography. The oxidation stability and oxidation degree along with the dynamics of the oxidation processes during frying were assessed by Rancimat method along with UV spectroscopy and electric impedance spectroscopy. The thermal behaviour of the oils and more precisely the amount of polar compounds formed during frying and their effect on the recrystallization phenomena are examined by differential scanning calorimetry.

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2. Introduction

Deep frying is a widely used food preparation technique both in households and restaurants (Choe and Min, 2007). It is also one of the most frequent choices for food cooking due to its simplicity and accessibility. The process of deep frying takes place at high temperatures (160–190 °C) and the oil acts as a heat and mass transfer media that results in a crispy texture and varying flavour for the foodstuff (Kaur et al., 2020; Wiege et al., 2020). Despite its feasibility, deep frying is a complex physicochemical process which is highly influenced by many factors, such as the type and quality of the oil (Yılmaz et al., 2023). As a result of thermal and oxygen exposure, different chemical reactions happen in the oil as hydrolysis, oxidation, polymerization, and isomerization result in thermal and oxidative decomposition of the oils (Dobarganes and Márquez-Ruiz, 2015; Boskou et al. 2006; Turan et al. 2022).

The complexity of these reactions is directly linked to the properties and quality of the used oil and particularly to its fatty acid composition. As a result of different thermo-oxidative reactions, the composition of the oil is changing and the presence of smaller reactive molecules such as free radicals, cyclic fatty acids, or some volatile oxidized compounds may be detected. Their presence leads to alterations in the sensory, functional and nutritional properties of the oils. The extent to which these reactions may occur depends on the amount of unsaturated fatty acids in the oil, the frying time and temperature, and the type of food product that is being fried (Yılmaz et al., 2023; Habarakada, et al. 2021).

It is important to know and to detect the types of byproduct compounds present in oil during thermal processes, due to their potential hazardous effect on the consumers' health (Quek et al. 2022). Back in the 2000's, an international symposium for deep frying was proposed to analyze fats and oils by determining their polar compound content. However, this technique is expensive and time consuming and researchers aim to develop or propose other more effective and accessible methods for quality control of oils before and/or after deep frying (Donner et al. 2000). Many researchers headed toward using change in viscosity and dynamic interfacial tension (Wiege et al. 2020). Changes in these parameters turned out to be indicative of oil deterioration, yet not informative enough about the extent of oil decomposition in different types of oils and their blends, and therefore need to be combined with other techniques in order to have clearer understanding of the occurring decomposition (Cunha et al. 2024).

The main aim of the present study is to establish the potential of different physical and physico-chemical experimental approaches to detect changes in the properties of oils before and after deep frying for up to 9 hours. For this purpose, a comparison between acid values, refractive indices, induction time, UV-VIS spectrophotometry, differential scanning calorimetry, DSC, and Electric impedance spectroscopy will be done. To check the sensibility, these 3 types of oils were chosen: refined sunflower, high-oleic sunflower (HOSO), and rapeseed.

3. Materials and methods

Materials: Refined Sunflower oil (trademarked "Klas"), high oleic sunflower oil (HOSO) and rapeseed oil were obtained from a local Bulgarian market. All other chemicals used in the physical and chemical testing were of analytical grade.

Frying procedure

The frying was performed based on the procedure reported by Holgado (Holgado et al. 2024) with small modifications. 700 ml of the oils were placed in a fryer at 180°C and used to fry potatoes, 2 kg in total divided in portions of 100 g. Each portion required 10 mins time to be ready. After each single portion the oil was left at that temperature for 20 mins. Small samples were taken at specific intervals up to the 9th hour of thermal usage. After cooling to room temperature, the samples were filtered and stored at 4°C in a refrigerator.

Determination of fatty acid composition. Fatty acid composition of the oils was determined by gas chromatography (GC), according to ISO 12966-4:2015 Animal and vegetable fats and oils — Gas chromatography of fatty acid methyl esters — Part 4: Determination by capillary gas chromatography. Fatty acid methyl esters (FAMEs) were prepared by pre-esterification of the samples with 2% sulphuric acid in absolute methanol at 50 °C, as describes ISO 12966-2:2017 Animal and vegetable fats and oils — Gas chromatography of fatty acid methyl esters — Part 2: Preparation of methyl esters of fatty acids. Determination of FAMEs was performed on Agilent 8860 gas chromatograph equipped with a capillary column DB Fast FAME (30 m 0.25 mm 0.25mm film thickness) and a flame ionization detector. The column temperature varied from 70 °C (1 min) to 180 °, at a rate of 6 °C/min, and then from 180 ° to 250 °C at a rate of 5 °C/min; the temperature of the injector was 270 °C and that of the detector was 300 °C, respectively.

Acid value. Acid values were determined titrimetrically, according to ISO 660:2009. Animal and vegetable fats and oils. Determination of acid value and acidity (p. 5).

Oxidative stability. Oxidative stability of the oils was determined by measuring the induction period via conductometric detection of volatile compounds. Rancimat apparatus Methrom 679 was used at 100 °C with an air flow rate of 20 $L.h^{-1}$, as described in ISO 6886:2016. Animal and vegetable fats and oils. Determination of oxidative stability (accelerated oxidation test).

Refractive index measurement. The refractive indices were determined by a standard Abbe refractometer. The measurements were performed at a temperature of 20 °C with an accuracy of ± 1×10^{-4}. The refractometer was calibrated with water (n_D=1.3330) and isooctane (n_D=1.3915) at 20°C.

Differential scanning calorimetry. The crystallization and melting phenomena of the investigated oils were studied using a differential scanning calorimeter (DSC) 204F1 Phoenix (Netzsch Gerätebau GmbH, Germany). The analysis was carried out during the following temperature regimen: cooling down from 25 °C to –70 °C with a cooling rate of 2 K/min; isothermal step at –70 °C for 10 min; heating from –70 °C up to 100 °C with a heating rate of 5 K/min.

UV-visible (UV-Vis) spectrophotometry. Here, the standard method of the UV spectroscopy was performed on a *Metertech UV/VIS Spectrophotometer SP-8001*.–0.2% w/v–solutions of oil in iso-octan (2,2,4 trimethylpentane) were prepared, mixed well and poured into a quartz cuvette with an optical path-length of 10 mm. Linearity, wavelength, and photometric accuracy in the UV range were verified before the measurements. The spectra in the UV range (220-300 nm) were recorded with a 1-nm resolution and calibrated by means of a pure solvent spectrum. Special attention was paid to the Absorbance (**Abs**) at about 232 and 268 nm, which correspond to the existence of conjugated dienes and trienes, respectively (Malavi et al., 2023, Hashem et al. 2020).

Electric impedance spectroscopy (EIS): EIS *1910 Inductance analyzer* (Quad tech, USA), was employed to investigate the dielectric characteristics of the oils. For the EIS experiments, a volume of 7 ml oil was placed into a specially designed measuring cell. All tests were performed in triplicate. The vegetable oils show almost perfect capacitive behavior i.e. the phase angle of the electric impedance is -90°, which justify the investigation of the dielectric dispersion, ε' (as the real part of the relative permittivity). The parallel capacitance of the oil, C_p^{oil}, was measured in the frequency range of 100 Hz to 1 MHz (at least 100 experimental points). The values were then used to derive ε_1 with the help of the capacitances of the air (C_p^{air}) and the water (C_p^{water}) so that:

$$\varepsilon' = (C_p^{oil} - C_p^{air} - K_c) / K_c$$

where K_c is a calibration factor $K_c = (C_p^{air} - C_p^{water}) / (\varepsilon^{water} - \varepsilon^{air})$. K_c takes into account the specificity of the cell (stray capacitance etc.) and helps to eliminate any undesirable effects arising from the cell construction.

4. Results and discussion

Fatty acid composition

The results of the fatty acid composition analysis for sunflower oil, high oleic sunflower oil (HOSO), and rapeseed oil are presented in **Table 1**.

Table 1: Fatty acid composition of the investigated oil.

Fatty acid composition, %		Sunflower oil	HOSO	Rapeseed oil
$C_{16:0}$	Palmitic	6.4	5.0	4.4
$C_{18:0}$	Stearic	3.3	2.9	1.4
$C_{18:1}$	Oleic	34.5	82.8	64.7
$C_{18:2}$	Linoleic	54.0	7.3	18.8
Saturated fatty acids, %		11.0	9.1	6.4
Unsaturated fatty acids, %		89.0	90.9	93.6
Monounsaturated fatty acids, %		34.9	83.4	66.2
Polyunsaturated fatty acids, %		54.1	7.5	27.4

Fourteen fatty acids were identified. The major component in the sunflower oil "Klas" is the linoleic acid (54.0%), followed by oleic acid (34.5 %). The fraction of saturated fatty acids was represented by palmitic acid (6.4 %) and stearic acid (3.3 %). The major component in HOSO is oleic acid (82.8 %), followed by linoleic acid (7.3 %), palmic acid (5.0 %), and stearic acid (3.3 %). The oleic acid content of rapeseed oil (64.7 %) is much higher than the sunflower oil; the linoleic acid is 18.8 %. The saturated acid content is close to

that of the sunflower oils. The amount of the other fatty acids is lower than 0.5 %.

Acid value and oxidant stability

The acid values of the oils during the frying process (**Table 2**) do not show a regular tendency to increase during frying.

Table 2: Acid value (AV, mgKOH/g) and oxidative stability (IP, h) of the investigated oils during the frying process.

Frying time, h	Sunflower		High oleic sunflower oil (HOSO)		Rapeseed oil	
	AV, mgKOH/g	IP, h	AV, mgKOH/g	IP, h	AV, mgKOH/g	IP, h
0	0.62±0.00	13.80	0.33±0.00	46.4	1.13±0.03	16.9
1	0.56±0.01	11.70	0.36±0.02	44.8	1.01±0.03	16.2
2	0.67±0.05	9.30	0.39±0.03	43.8	1.26±0.10	13.0
3	0.84±0.02	9.20	0.42±0.02	42.8	0.96±0.02	12.6
4	0.91±0.01	9.17	0.30±0.00	39.3	1.18±0.01	14.8
5	0.85±0.01	8.85	0.62±0.03	28.6	1.22±0.05	12.0
6	0.98±0.00	7.67	0.48±0.00	26.2	1.33±0.03	12.4
7	0.96±0.02	7.35	0.53±0.04	21.8	1.35±0.03	9.30
8	1.10±0.10	7.12	0.56±0.00	15.7	1.35±0.05	9.12
9	0.96±0.04	6.30	0.57±0.03	10.43	1.30±0.02	8.48

The results show that the frying process leads to complex hydrolysis and thermal degradation processes. A smooth increase in acid value from 0.56 mg KOH/g at the 1st hour to 1.10 mg KOH/g at the 8th hour is observed for the sunflower oil, with slight fluctuations at the 5th hour. The acid value initially increases during frying, decreases slightly in the middle of the process, and then continues to grow slowly.

A similar trend is observed for the other two oils: the acid value (AV) for HOSO ranges from 0.36 mg KOH/g at the 1st hour to 0.57 mg KOH/g at the 9th hour, and for rapeseed oil, it ranges from 1.01 mg KOH/g at the 1st hour to 1.35 mg KOH/g at the 8th hour, with a slight decrease at the 4th hour (0.30 mg KOH/g) for HOSO and at the 3rd hour (0.96 mg KOH/g) for rapeseed oil.

Generally, the values of the AV increase as free fatty acids are released due to the hydrolysis of the triacylglycerol. This process continues until all susceptible fatty acids have been hydrolysed. The results from the present study indicate a non-linear increase with fluctuations at certain time points. The decrease in AV around the middle of the frying time can be explained by possible reactions between the free fatty acids (FFAs) and the frying food. Other reasons are also that some FFAs are volatile at frying temperatures; they may react with mono- and diacylglycerols, as well as undergo oxidation or polymerization, leading to a temporary drop in AV. Other than that, the distinct fatty acid composition of the oils (high oleic vs. standard sunflower vs. rapeseed) may lead to different rates of hydrolysis and oxidation, explaining variations of the AV in the examined glyceride oils.

The induction period (IP) was also examined during the frying process. An increase in the frying time leads to a decrease in IP value for all samples. HOSO is found to be the most stable vegetable oil among the analyzed oils. The IP of the control oil was initially 46.4 hours, but decreased to 10.43 hours by the end of the process, indicating that the control oil is approximately four times more stable than the oils investigated here after 9 hours. The other oils (sunflower and rapeseed oil) were more unstable against the process of oxidation during the frying process. The IP decreases from 13.80 to 6.30 h for sunflower oil and from 16.9 to 8.48 h for rapeseed oil.

Refractive index

The refractive index values of the oil during the frying process are presented in **Fig. 1**. The obtained values show a significant difference in the mean refractive indices of all investigated oils. The refractive index of the oils increased with frying time. A similar finding was shown by Mudawi et al. (Mudawi et al. 2014). The changes in the refractive index are as follows: from 1.4660 (0 hour) to 1.4668 (9th hour) for HOSO, from 1.4691 to 1.4705 for sunflower oil, and from 1.4705 to 1.4720 for rapeseed oil, respectively. The highest values were observed at the 9th hour, regardless of the oil type. The increase of conjugated fatty acids with time leads to changes in the density and the colour of the oils, so that the refractive index changes as a result of thermal degradation (Godswill et al. 2018). The continuous increase in the refractive index of the oil during repeated frying indicates that deep frying increases their rancidity. Therefore, repeated frying using the same vegetable oil should be discouraged.

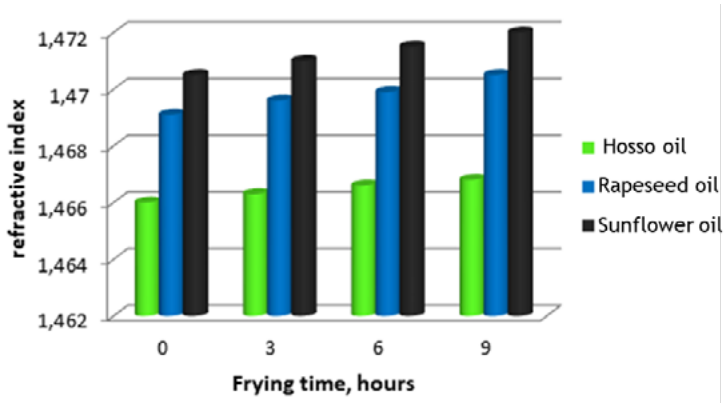


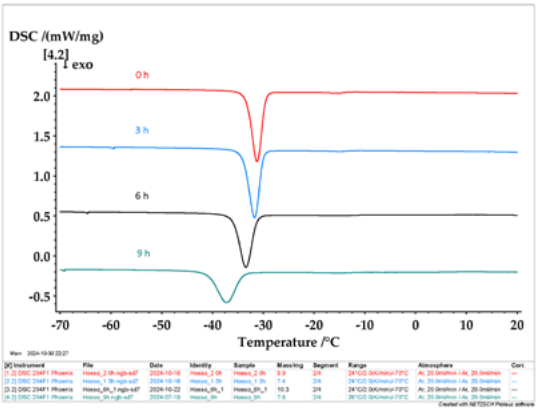
Fig. 1 *The mean values of refractive indices of the oils before and after frying.*

Differential scanning calorimetry

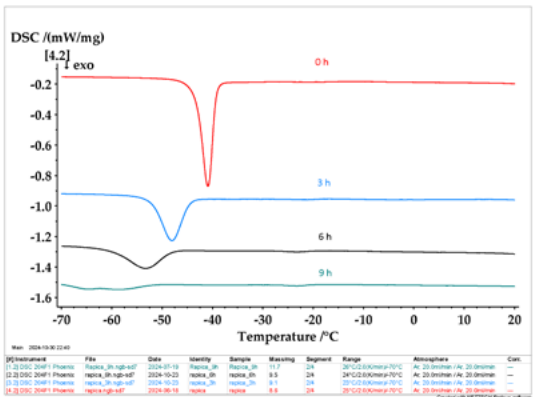
The DSC curves of the studied oil are presented in Fig. 2 (a-c). The cooling thermograms of the oils show a single peak, which corresponds to the exothermic crystallization phenomena. For all types of oil, the temperature and the enthalpy of crystallization decrease linearly with increase in frying time (Table 3). Similar results have been reported by other authors (Al-Khusaibi et al. 2022) and they are attributed to the oxidation process and changes in the chemical composition. In the case of oxidized oils, the chemical composition is affected by the polar compounds formed during frying i.e. hydroperoxides, free fatty acids, mono- and diacylglycerols, glycerol, and oxidized polymers (Chen et al. 2021). In their work Cuvelier et al. (Cuvelier et al. 2012) established a not oil-specific correlation between the total polar compounds (TPC) and the crystallization parameters of vegetable oils, taking into account their polyunsaturated fatty acid content (PUFA), expressed in percentage.

$$TPC\ (\%) = (a - b \cdot \Delta H) + c \cdot PUFA \cdot exp\left(-\frac{PUFA}{d}\right) \quad (1)$$

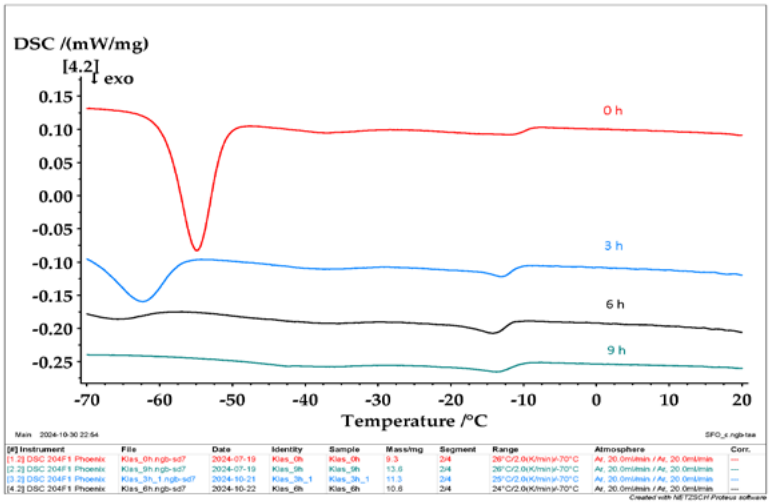
where ΔH is the specific enthalpy of crystallization in J/g. The *a*, *b*, *c,* and *d* parameters have the following values: a = 35.27 ± 1.573, b = 0.7492 ± 0.0402, c = 5.804 ± 0.600 and d = 10.13 ± 0.70.



a)



b)



c)

Fig. 2. *DSC thermograms for crystallization phenomena of a) HOSO oil, b) rapeseed oil, and c) sunflower oil "Klas"*

The level of TPC for the sunflower, HOSO, and rapeseed oil are presented in table 3. In general, the level of TPC increased linearly across frying time with the coefficient of determinations of $R^2 > 0.98$. The lowest TPC levels were calculated for high oleic sunflower oil (HOSO) and the highest for the sunflower oil "Klas", for which at the sixth hour a value of 35.6% was reached. Similar results were reported by Tarmizi et al., who studied the oxidation process of palm olein, soybean oil, rapeseed oil, and sunflower oil during frying (Tarmizi et al. 2019). Taking into consideration that a maximum limit of up to 25% has been suggested in official legislations from different countries (Firestone, 2007), it is suggested that only HOSO oil could be used for 9 hours of frying.

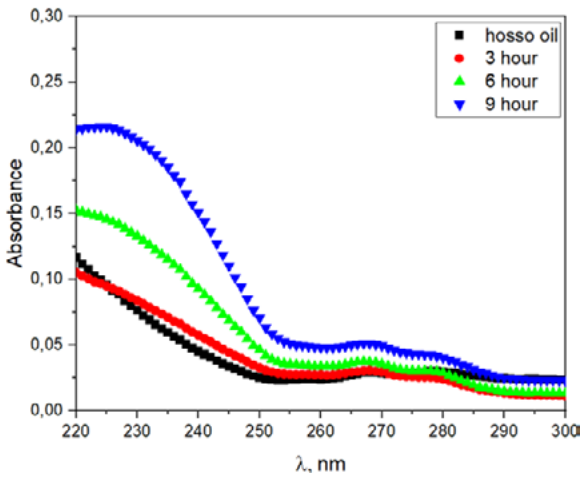
Table 3: The enthalpy of crystallization (ΔH), crystallization temperature (T_c), and total polar compounds (TPC) of the investigated oils.

Frying time, h	Sunflower oil			High oleic sunflower oil (HOSO)			Rapeseed oil		
	ΔH, J/g	T_c, °	TPC, %	ΔH, J/g	T_c, °	TPC, %	ΔH, J/g	T_c, °	TPC, %
0	31.1	-54.9	13.4	64.51	-31.2	7.6	55.6	-40.9	4.2
3	12.9	-62.5	27.1	61.60	-31.7	9.8	40.1	-48.0	15.8
6	1.48	-65.3	35.6	58.70	-33.4	12.0	31.2	-53.3	22.5
9	-	-	-	54.18	-37.2	15.4	11.7	-59.0	37.1
R^2	**0.9828**			**0.9866**			**0.9813**		

UV-Vis spectroscopy

The UV absorbance (**Abs**) spectra of the investigated oils with the frying time are shown in **Fig.3** (a-c).

a)



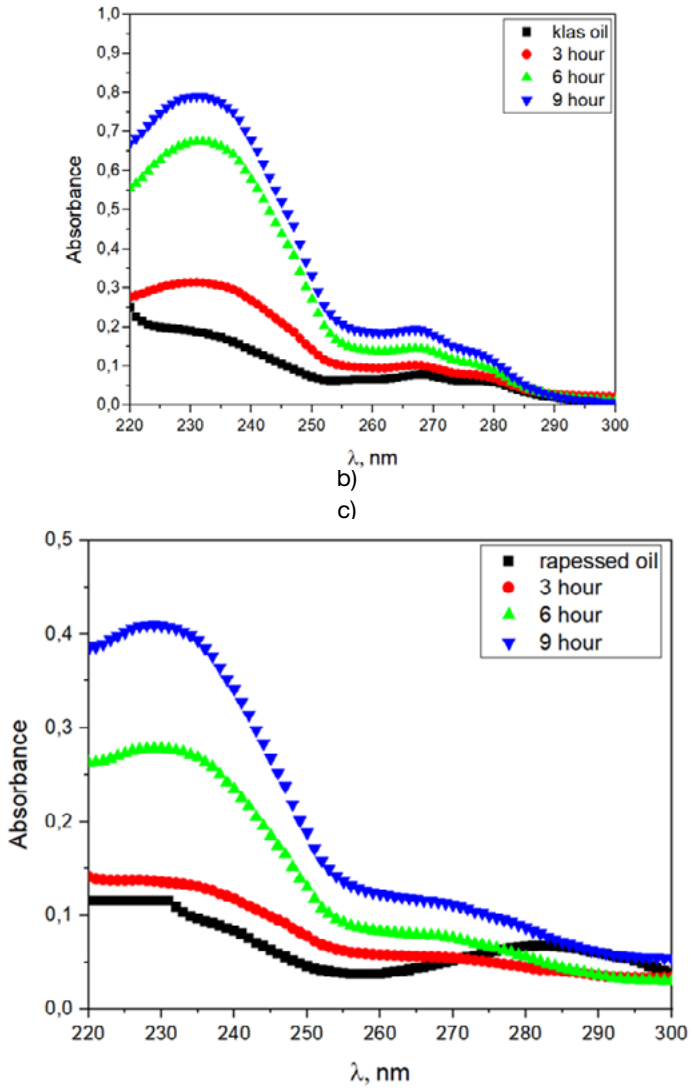


Fig. 3. *Spectra of absorbance during the frying process at 220-300 nm of: a) HOSO oil; b) Sunflower "Klas" oil; c) Rapeseed oil. The numbers in the legend denote the hours of thermal usage.*

The results presented in figure 3 show that:

- UV-Vis spectra for all investigated oils are characterized with two peaks at wavelengths 232 nm and 268 nm. The absorbance at 232 nm corresponds to primary oxidation processes due to the formation of conjugated dienes as a consequence of the peroxidation products of sunflower biodiesel, whereas the absorbance at 268 nm appears as a result of secondary oxidation processes, associated with the formation of conjugated trienes. Analogous results were obtained by other researchers (Malavi et al., 2023; Hashem et al. 2020);
- Values of the absorbance at 232 nm increased from 0.07, 0.19, and 0.11 (0 hour) to 0.22, 0.80, and 0.41 (9 hour) of frying for HOSO, sunflower "klas", and rapeseed oil, respectively. The largest changes in the spectra occur for sunflower oil, followed by rapeseed oil, and the smallest for high oleic oil. These observations correspond to the findings of Šegatin et al. 2020, where the oils were kept at a temperature of 180°C for up to 40 hours. However, our results deviate from the monotonic increases of the band absorbance with time due to the large number of complex chemical processes occurring not only with the air and the moisture in it, but also with the substances of the potatoes;
- The absorbance of the oils increased with the frying time (0-9 hours) of the potato chips.

The time variation of the Abs of the two main bands (at 232 nm and 268 nm) for the investigated oils is shown in **Fig.4(a-c)**. and the alternation in the spectra, more precisely in the absorbance for the two main bands (at 232 nm and 268 nm) for sunflower oil is shown in **Fig.4b**. Both Abs curves show double maxima, divided by a minimum at the 4th hour. The second maximum of the 232-nm curve is more pronounced than that of the 268-nm curve. Such complex behavior is observed in the acidic value (AV) and induction period (IP) value trends, but the extreme values here do not correspond to those of AV and IP. In fact, the tendencies of the

HOSO oil are the same as those of sunflower but the Abs value differences are smaller.

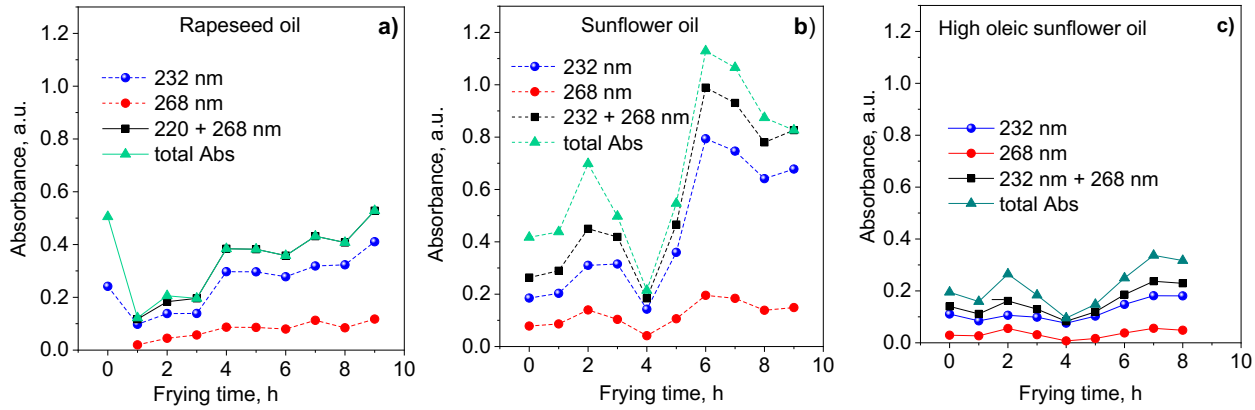


Fig. 4. *Absorbance of the main two peaks at 232 nm and 268 nm for the different oils dependent on time of frying: a) Rapeseed oil; b) Sunflower oil; c) High oleic sunflower oil.*

Electric impedance spectroscopy

In **Fig.5a** a representative plot of frequency dependence on frying time for rapeseed oil is shown. As discussed by many authors (Valantina, 2021; Šegatin et al. 2020), the values are almost independent of the frequency in the range above 150 kHz. The initial low values could be attributed to some pre-electrode processes in the measuring cell. At higher frequencies, the curves appear parallel to each other so for comparison purposes the values at fixed frequency (600 kHz) will be discussed. In **Fig.5b** the variation of with frying time for all three oils is given. The values for the rapeseed oil initially decrease and then gradually increase. For the sunflower oil a double maxima curve is presented. The limits of EIS is demonstrated by the high oleic sunflower oil results, where the values are almost independent of the frying time, which deviates from the UV Abs trend.

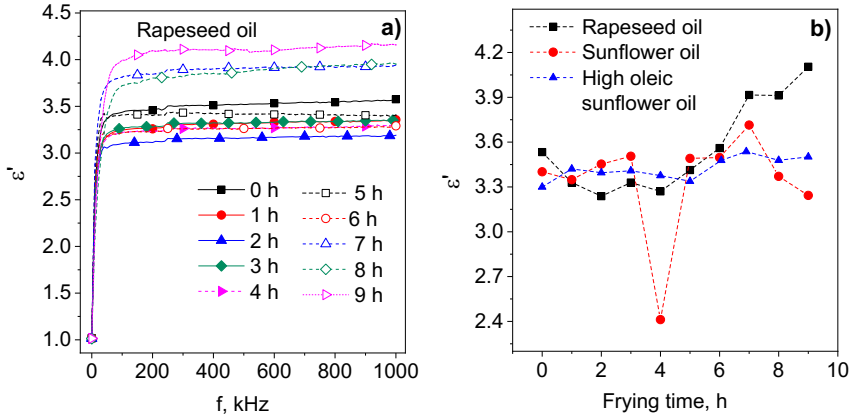


Fig. 5. a) Dielectric dispersion, ε', dependent on frequency for Rapeseed oil for different frying times (the curves are based on 100 experimental points); b) ε' variation with frying time for all used oils. The Standard Deviation was in the limits of 0.005.

5. Conclusion

The aim of the present study was to evaluate the rancidity development during deep frying for 3 types of oils by different physical and chemical methods. The deep frying process affected induction times, making them shorter. With an increase in the frying time, refractive indices of all oil types along with their recrystallization enthalpies, due to the presence of polar compounds, increased. As a result of oxidation processes and formation of conjugated trienes, an alternation in the UV-VIS spectra of all oils in the region of 232 nm and 268 nm was observed. The least changes in all measured parameters were found for the HOSO type of oil.

6. Acknowledgments

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Különböző típusú növényi olajok fizikai-kémiai tulajdonságainak összehasonlítása sütés előtt és után

Kulcsszavak: olajban sütés, olaj oxidáció és termikus bomlás, zsírsav-összetétel, poláros vegyületek, UV-VIS olajspektrumok, olajok fizikai-kémiai jellemzése, növényi olajok

Összefoglalás

Az olajban sütés az egyik leggyakrabban alkalmazott ételkészítési módszer. A sütési folyamatban alapvető fontosságú a megfelelő olaj kiválasztása, mivel az olaj szerepet játszik a hőátadásban és a termék impregnálásában. A magas hőmérsékleten történő ismételt használat számos oxidációs, polimerizációs és termikus bomlási reakciót eredményez, amelyek az olajok fizikai, kémiai, táplálkozási és érzékszervi tulajdonságainak megváltozásához vezetnek. Mivel a változások különböző folyamatok eredményeként alakulnak ki, azokat nem lehet egyetlen módszerrel értékelni. A folyamatok mértéke az egyes olajtípusok esetében eltérő. Ezért a jelen tanulmány célja három növényi olaj, nevezetesen a finomított napraforgóolaj, a magas oleinsavtartalmú napraforgóolaj (HOSO) és a repceolaj minőségi változásainak vizsgálata különböző fizikai és fizikai-kémiai módszerek alkalmazásával. Az általános kémiai paramétereket, mint például a savszámot és a zsírsav-összetételt, standard módszerekkel, nevezetesen titrálással és gázkromatográfiával mértük. Az oxidációs stabilitást és az oxidációs fokot, valamint a sütés során végbemenő oxidációs folyamatok dinamikáját Rancimat-módszerrel, UV-spektroszkópiával és elektromos impedancia-spektroszkópiával határoztuk meg. Az olajok termikus viselkedését, pontosabban a sütés során képződő poláris vegyületek mennyiségét és azok hatását az újrakristályosodási jelenségekre DSC (differential scanninc calorimetry, differenciális pásztázó kalorimetria) módszerrel vizsgáltuk.

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Possibilities for discriminating between Tenebrio molitor *larvae fed with plastic and conventional substrates*

Keywords: *Tenebrio molitor,* plastic waste, mealworm, circular economy, Near Infrared Spectroscopy

1. Abstract

The rapid increase in the global population is driving up the demand for high-quality biological proteins and contributing to rising plastic production and plastic waste. Research indicates that certain larvae may break down plastic, which is resistant to biodegradation, due to bacteria and enzymes in their gut. This study aims to identify a measurement method suitable for industrial use to detect plastic consumption by larvae, which were fed three distinct diets: a mixture of flour and carrot (control), white Styrofoam (wPs), and grey Styrofoam (gPS) enriched with activated carbon. In addition to Styrofoam (polystyrene (PS)), the second two groups were given a mix of flour and carrots. The measurements were conducted using near-infrared spectroscopy, and the data were analysed using Matlab2019a software. A variety of classification algorithms were employed to separate the three groups following pretreatment of the spectra. The linear support vector machine (SVM) model demonstrated an 88% accuracy rate in separating the three groups. Larvae fed on polystyrene-free feed were accurately identified, while larvae fed on two types of polystyrene were less well differentiated. The classification methods were also tested for two groups: larvae fed with polystyrene-containing and polystyrene-free feed. The results indicate that the linear SVM was 92% efficient. At the same time, the quadratic SVM and cubic SVM demonstrated 100% efficiency. The results show that the appropriate model can be employed to differentiate between larvae that consume polystyrene and those that consume plastic-free diets. The underlying mechanism responsible for this separation, whether it be undegraded microplastics in the larval gut or other substances accumulated from polystyrene, requires further investigation.

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2. Introduction

The global population is increasing rapidly. It is projected to reach 9 billion by 2050 and 10 billion by 2100 (Internet 1). This rapid growth will increase demand for high biological value animal proteins, which the agricultural and food industries will find challenging to meet. (Kemenczei et al., 2016). The speed of livestock production and processing, along with the amount of land, feed production, and water used for livestock production, can also present a challenge (Miglietta et al., 2015). One potential solution is the utilisation of alternative proteins, including those derived from plants, aquaculture and insect proteins (National Academies of Sciences, Engineering, and Medicine, 2022). The processing of insect proteins presents several advantageous characteristics, in addition to their exceptionally high nutritional value. They are potential food and feed ingredients due to their high protein content, essential amino acid content, and ideal fatty acid composition (Costa et al., 2020). Their production is also environmentally beneficial, as they have significantly lower greenhouse gas and ammonia emissions than other agricultural meat processing methods and require less water and land (van Huis et al., 2021).

In addition to their excellent nutritional properties, it is important to consider the various food hygiene and food safety factors and risks associated with edible insects in the food and feed industry. “The food consumed must, therefore, be expected to contain the appropriate proportions of proteins, carbohydrates, fats, macro- and microelements, vitamins, and other active substances necessary for life. However, it must not contain pathogenic microbes, other biological agents harmful to health, chemical substances (in excess of the limits set forth by law), and physical contaminants” (Laczay, 2012). In the case of insects, chemical hazards may include the presence of toxins and heavy metals, which accumulate in their bodies and enter the food chain. Insects may come into contact with these substances in their natural habitat or through ingesting contaminated feed. A further significant issue in food hygiene is the potential presence of microbiological hazards. Regarding edible insects, microbiological hazards include, in addition to the individual microbiota of the insects, bacteria and viruses that attack the insects and which currently do not pose a risk to humans. However, paying attention to this area is important to avoid possible adverse effects. The FAO’s Edible Insects: Future Prospects for Food and Feed Security (Forestry Papers 171, 2013) addresses the potential risks of zoonotic infections. Given the significant taxonomic differences between insects and humans, the risk of zoonotic infections is not expected to be significant. However, there is a potential risk of contamination by viruses, bacteria, and parasites that may threaten humans and animals due to inadequate husbandry and handling and cleaning practices.

As a secondary consequence of population growth and economic change, income levels have risen, leading to an increase in plastic production and waste by 2019. Consequently, the quantity of plastic waste produced has increased by more than 100% over the same period (OECD,2022). Plastics are employed in many applications across numerous industrial sectors, including construction, textiles, transportation, electronics, and packaging for various consumer products and foodstuffs. The most significant issue is the use of single-use plastics for packaging and other applications, given their limited lifespan of less than one year and subsequent disposal as waste (Rhodes, 2018). The natural breakdown of plastic waste is a challenging process. Various environmental, physical, and physicochemical processes result in fragmentation and disintegration into micro- and nanomaterial particles. These particles are now ubiquitous in all parts of the world, including on land, freshwater basins, seas and oceans, marine sediments, and even air. These substances present a significant environmental and wildlife hazard and pose a considerable risk to human health, contributing to major public health concerns. Micro- and nanomaterials can gain access to the body via ingestion, inhalation or dermal exposure, with the potential to cause a range of significant health issues (Ali et al., 2024; Pilapitiya & Ratnayake, 2024; Hirt & Body-Malapel, 2020). Styrofoam, or foamed polystyrene (PS), is one of the most commonly used types of plastic, produced by the polymerisation of styrene monomers. Styrofoam is made by heating polystyrene granules (Kik et al., 2020). Styrofoam is also known as expanded polystyrene (EPS) and its properties include being thermoplastic, durable, permanent, and resistant (Febriansya et al., 2024).

It is important to identify solutions to the food safety and waste management issues that arise from a growing population. The European Commission’s Circular Economy Action Plan may offer a suitable solution to these problems. The Action Plan will focus on utilising farming techniques that minimise the consumption of raw materials to a level that the Earth can sustain without further deterioration to ensure the planet’s future (Internet wang2). Research by Madau et al. (2020) indicates that processing edible insects as food and feed represents a natural and essential component in the evolution of a circular economy. This is because there is growing evidence that some species of invertebrates can consume and break down food waste, other by-products, and various plastics. The larvae of the *Tenebrio molitor* have been the subject of extensive research due to their notable ability to degrade polystyrene. In their 2022 study, Wang and Tang investigated the effects of different polystyrenes on the intestinal rumen of *Tenebrio molitor*. They evaluated the vital signals in the gut and faecal fluid using RNA-Seq technology. The findings suggest that consuming polystyrene may result in delayed larval development. The findings of an additional study indicate that larvae fed with polystyrene foam exhibited comparable survival rates to those nourished with conventional (wheat bran) feed

during the initial month. The study employed gel permeation chromatography, nuclear magnetic resonance spectroscopy, and thermogravimetric Fourier transform infrared spectroscopy to analyse faecal samples from larvae fed Styrofoam. The results corroborate the hypothesis that polystyrene molecules in the intestinal tract are cleaved and depolymerised (Yang et al., 2015). In a study by Nakatani et al. (2024), expanded polystyrene (EPS) was provided as a dietary supplement to *Tenebrio molitor* larvae. The resulting decrease in the molecular weight of the polystyrene was examined using FT-IR and py-GC/MS spectrometry. The results demonstrated a 33% reduction in the molecular weight of digested polystyrene following a one-week feeding period. Furthermore, the findings indicated that the survival rate of larvae reared on EPS was higher than that of starved larvae, suggesting that EPS may serve as a nutrient source for the larvae. However, there was no observable weight gain in larvae reared on EPS feed. In a 2022 study (Machona et al., 2022), larvae were fed on three distinct types of feed for seven days. The feed settings were the following: a control group (fed wheat flour and carrot), a polystyrene group, and a third group that received expanded polystyrene as a substrate. After seven days, the survival rate and weight variation were investigated, and distinct bacterial strains were isolated and identified from the intestinal tract of the polystyrene-fed larvae. The survival rate of the feeding experiments was 90% for the larvae fed with the control diet and the beet-polystyrene mixture. In comparison, a survival rate of 85% was observed for larvae fed with polystyrene alone. Following isolation, the bacteria were subjected to morphological and DNA sequence analyses for identification. Gram-negative bacteria were found in the intestinal tract of the mealworms based on three isolates, and the sequencing results showed that the bacteria responsible for the degradation in the isolates were the same as those found in the study: *Klebsiella oxytoca* ATCC 13182, *Klebsiella oxytoca* NBRC 102593 and *Klebsiella oxytoca* JCM 1665. In 2022, an in vitro cytotoxicity test was conducted on starch derived from *Tenebrio molitor* larvae fed polystyrene. The objective was to assess the effect of this substance on the viability of an oestrogen-dependent MCF-7 cell line. Additionally, in vivo experiments were performed on male Sprague-Dawley rats. In the study, rats were fed daily for 5 weeks with a powder made from larvae previously fed with polystyrene as a forage. Following this, a series of toxicological tests were conducted including clinical signs, body and organ weights, food consumption, haematology, serum chemistry, haematoxylin and eosin staining of the liver and kidney. The results demonstrated that the powder did not elicit any specific adverse effects. Consequently, the study concluded that it was acceptable to utilise the larval powder in high-protein animal feed (Choi et al., 2022).

1.1 Regulation

In the European Union, the conditions for the marketing of novel foods are governed by Regulation (EU) 2015/2283 of the European Parliament and of the Council. “Novel Food is defined as food that had not been consumed to a significant degree by humans in the EU before 15 May 1997, when the first Regulation on novel food came into force.” (Internet 3). In accordance with EU regulation 2015/2283 of the European Parliament and of the Council, the placement of novel foods on the market within the European Union is contingent upon their inclusion in the list of novel foods. The aforementioned list is the EU regulation 2015/2283, which was subsequently amended on 1 June 2021 (amendment to the European Commission Implementing Regulation 2017/2470: European Commission Implementing Regulation 2021/882) to permit placing four insect species within the EU on the market. The European Commission Implementing Regulation 2017/2470 specifies the insect species that are permitted for use, the forms in which insect-based ingredients may be incorporated, and the maximum permitted levels of such ingredients in various food types.

The legislative framework governing the marketing of insects as animal feed is more complex. The conditions for the utilisation of insects as animal feed are established in a number of legislative instruments. The eight species of insects that may be used as animal feed are listed in the amendment of Regulation (EU) No 142/2011/EU 2017/893. Following the amendment of Regulation (EU) No 999/2001 by Regulation (EU) No 2017/893, protein extracted from insects may be used for feeding aquatic animals as of 24 May 2017. Subsequently, in 2021, Regulation (EC) No 999/2001, as amended by Regulation (EC) No 2021/1372, will allow the feeding of pig and poultry with feed containing insect protein. The regulation stipulates that feed containing processed protein derived from farmed insects may contain less than 50% crude protein.

Furthermore, Commission Regulation (EU) 2017/893, which amends Annexes I and IV to Regulation (EC) No 999/2001 of the European Parliament and of the Council, as well as Annexes X, XIV and XV to Commission Regulation (EU) No 142/2011, states the following with regard to the provisions on processed animal protein: The term “farmed animals,” as defined in Article 3(6) of Regulation (EC) No 1069/2009, is extended to include insects reared for the production of processed protein derived from insects. The feed prohibitions set forth in Article 7 of Annex IV to Regulation (EC) No 999/2001, along with the feed regulations outlined in Regulation (EC) No 1069/2009, are applicable to the feeding of insects.

In the face of these regulations, it is expected that some farming ventures use prohibited materials as cheap feed for insects, such as certain plastics, which pose a potential health risk further down the feed and food chain. Also, such materials imported from third countries require investigation for safety purposes upon

entering the EU. Therefore, our study aimed to test an industrially applicable and possibly scalable approach for monitoring, with the use of Near Infrared Spectroscopy to detect whether insects have ingested plastic.

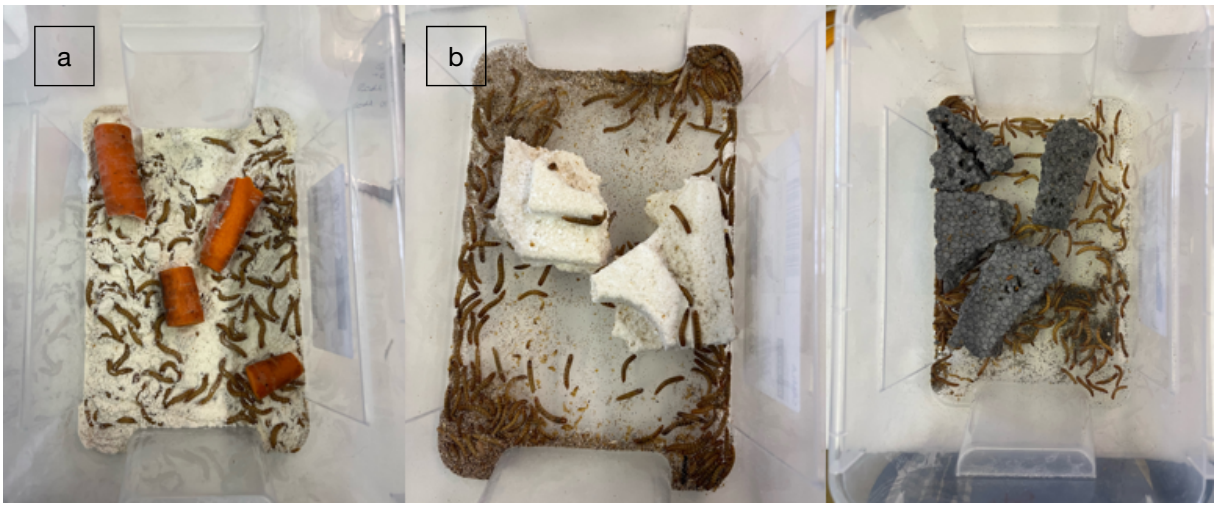
Materials and Methods

Tenebrio molitor

The larvae of Tenebrio molitor are one of four edible insect species that are permitted for marketing in the European Union for human consumption and animal feed (Internet 4). The *Tenebrio molitor* belongs to the order *Coleoptera*, family *Tenebrioidae*, class *Insecta*. The larvae of the mealworm are cold-blooded and environmental factors markedly influence their development. They have optimal conditions in dark, damp environments. The diet of the mealbug is omnivorous, with a preference for cereals and vegetables (Dalton et al., 2019).

The larvae used in the experiments were sourced from various pet and feed animal shops in Budapest. Since October 2023, we have been developing our omme with insects from the same source.

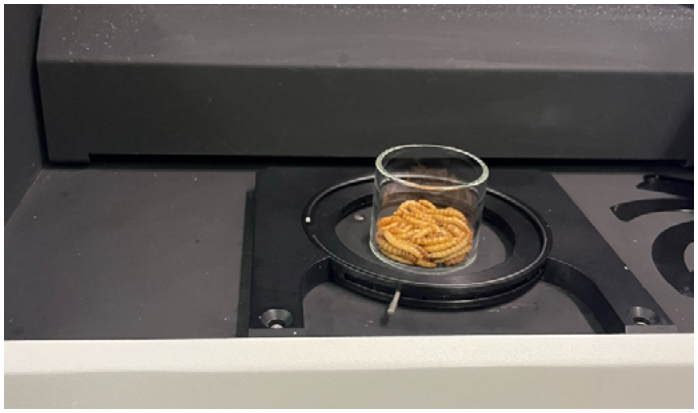
The larvae were given three different diets for varying lengths of time. The diets included a conventional mixture of carrot and flour (control) (**Figure 1/a**), white Styrofoam(wPS) used for packaging (**Figure 1/b**), and grey Styrofoam (gPS) enriched with activated charcoal (**Figure 1/c**), leftover from a previous project in our department. Larvae fed on polystyrene (PS) were given flour and carrots in addition to the PS.



1. Figure: The different feed types.
a: mixture of carrot and flour; b: diet contained white Styrofoam; c: diet contained grey Styrofoam

Near Infrared Spectroscopy (NIRS) Measurements

The NIRS measurements were conducted using a Metrohm NIRS XDS RapidContent Analyzer within the wavelength range of 400-2500 nm, with a resolution of 0.5 nm. The spectra were recorded from live larvae with three repetitions per sample (**Figure 2**).



2. Figure: Tenebrio molitor *larvae during the NIRS measurement*

The larvae are part of a multi-measurement experiment, therefore we used live larvae for the NIR scans. Since the goal of the study is to detect the fact of feeding with polystyrene, no chemical analyses were conducted, however some assumptions regarding the possible components and metabolic changes are explained in the Results section. Also, as Tsochatzis et al. (2021) conclude in their study, the gut microbiome can be vastly

different among distinct populations, as studies have found dissimilar bacteria in Tenebrio molitor larvae. This finding and the fact that the whole larvae is subject to further processing makes separate gut microbiome or gastrointestinal tract analysis superfluous.

Our design for the experimental setup was based on the work of Nina Kröncke and Rainer Benning (2022), in which live larvae were measured for moisture and protein content using near-infrared reflectance spectroscopy. The working principle and measuring method of the instrument ensures that the motility of the insects does not affect the readings. This is confirmed by the virtually identical spectra of the triplicates per sample measurement (average correlation coefficient is 0.9993).

Data Pretreatment and Analysis

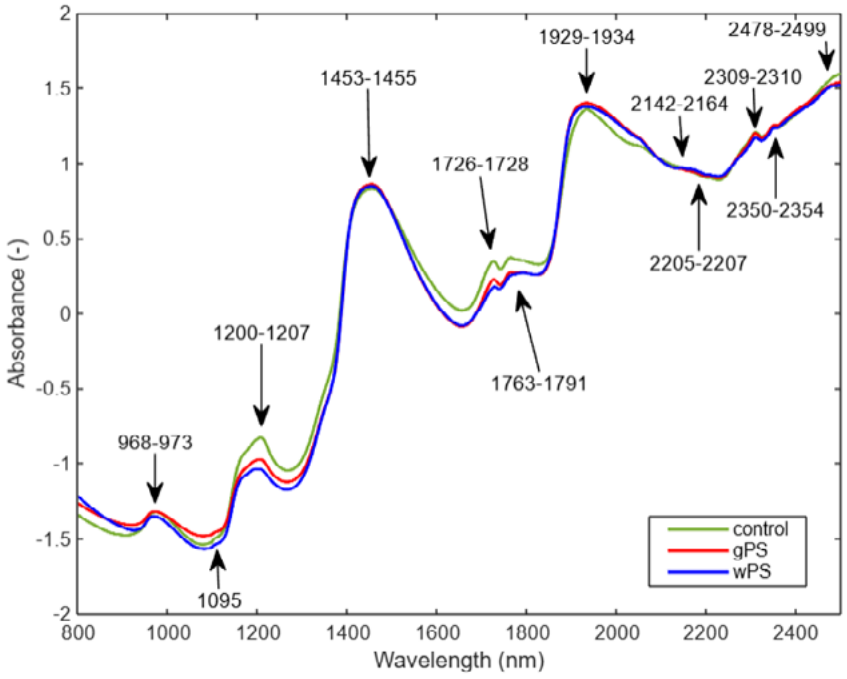
The raw spectral data were processed using MATLAB 2019a, between 800-2500 nm wavelengths. The preprocessing stage included smoothing with a second-order Savitzky-Golay filter and normalisation using Standard Normal Variate (SNV) correction. The input variables were the coefficients of the pretreated spectra, while the estimated classes were the different feed types. Various classification methods were employed for estimation, and the method yielding the best results was selected. The settings included three-fold cross-validation and principal component analysis (PCA) with 99% explained variance for efficient model building. The classification methods used were Discriminant Analysis (DA), K-nearest neighbours (KNN), Decision Trees, and Support Vector Machines (SVM).

3. Result and discussion

The correspondence between wavelengths and molecular bonds was assessed using the above-mentioned literature (Kröncke & Benning, 2022), the Practical Guide and Spectral Atlas for Interpretive Near-Infrared Spectroscopy, 2nd edition (Workman & Weyer, 2012) and the Handbook of Near Infrared Analysis 4th edition (Ciurczak et al., 2021). The wavelength values below indicate the chemical background of the peaks based on the above three references.

To be able to analyse the spectra of different feed types, the spectra were averaged by groups, followed by a preprocessing protocol described in 2.3. This process already showed visible dissimilarities between the groups, as shown in **Figure 3.**

3. Figure: Average of processed spectral data and main peaks of average spectras, by feed type (control - mixture of



carrot and flour; gPS - diet contained grey Styrofoam, wPS - diet contained white Styrofoam)

Several of the peaks are observed in all three averaged spectra, and are attributed to water, lipid, protein and chitin content, normally present in mealworms. The peaks around 970 nm most likely indicate the presence of water (Peñuelas et al., 1993). However, certain peaks, that are present in the PS-fed groups align with the absorbance spectrum and its specific peaks of pure crystalline polystyrene detailed in the works of Workman and Weyer (2012) and Ciurczak et al. (2021). These peaks occur at 1766 nm, 1791 nm, 1933 nm, 2144 nm, and 2354 nm, while certain plasticizers used in the manufacturing process contain aromatic rings, resulting in a peak at 2487 nm, but based on the table in the literature used, the peak may also refer to a C-H stretching &

C-C stretching combination in cellulose. According to other literature (Ozaki et al., 2021), peaks around 1767 nm can be attributed to the first overtone of C-H stretching in the CH2 groups of hydrocarbons and aliphatic compounds. In their work, Nina Kröncke and co-workers (2023) attributed peaks appearing between 1390 and 1450 nm to combined CH stretching and first overtone OH stretching, peaks appearing between 1925 and 2030 nm to combined and first overtones of OH and NH stretching, mainly related to water and protein content, and peaks at approximately 1146 nm and 1196 nm to second overtone C-H stretching. Peaks appearing between 1699 and 1797 nm may generally be related to fat and fatty acid content. On the other hand, based on the work of Workman and Weyer (2012) and Ciurczak et al. (2021), the peaks around 1935 nm can be attributed to O-H stretching and the HOH combination bonds of polysaccharides. The peaks around 2310 nm are probably C-H bending in lipids, while around 2350 and 2500 nm, probably the C-H stretching & C-C & C-O-C stretching combination of polysaccharides. Other manufacturing byproducts and chemical residues might contribute to the differences in the observed spectra, but these are not identified within the scope of the present study, and, therefore, are subject to speculation, and ultimately are not described in the present paper in detail.

The peaks in the 1010-1095 nm and 1140-1155 nm range are attributed to the second overtone of O-H and C-H, respectively, in accordance with another source on NIR spectroscopic measurement methods for determination of protein, total carbohydrate, and crude fat content in foxtail millet (Chen et al., 2013).

It is important to note that consumption of PS by the larvae may have an effect on the metabolism and therefore the over- or underproduction of certain compounds naturally present in them, and, as a result, can have an effect on the performance of classification (Tsochatzis et al. 2021). For instance the peaks around 1200 nm are generally attributed to lipids (Kröncke & Benning, 2022), but are more pronounced for the control group, and therefore we can assume that higher relative fat content can be associated with the consumption of PS. Larval fat/oil content can also be influenced by substrate quantity and quality, and environmental factors such as temperature and relative humidity (Bordiean et al., 2021; Syahrulawal et al., 2023).

Again, these are assumptions but they demonstrate the possible complexity of a correlative measurement technique such as NIRS.

4. Figure: Absolute values of spectral loadings of the first two principal components (PC1, PC2)

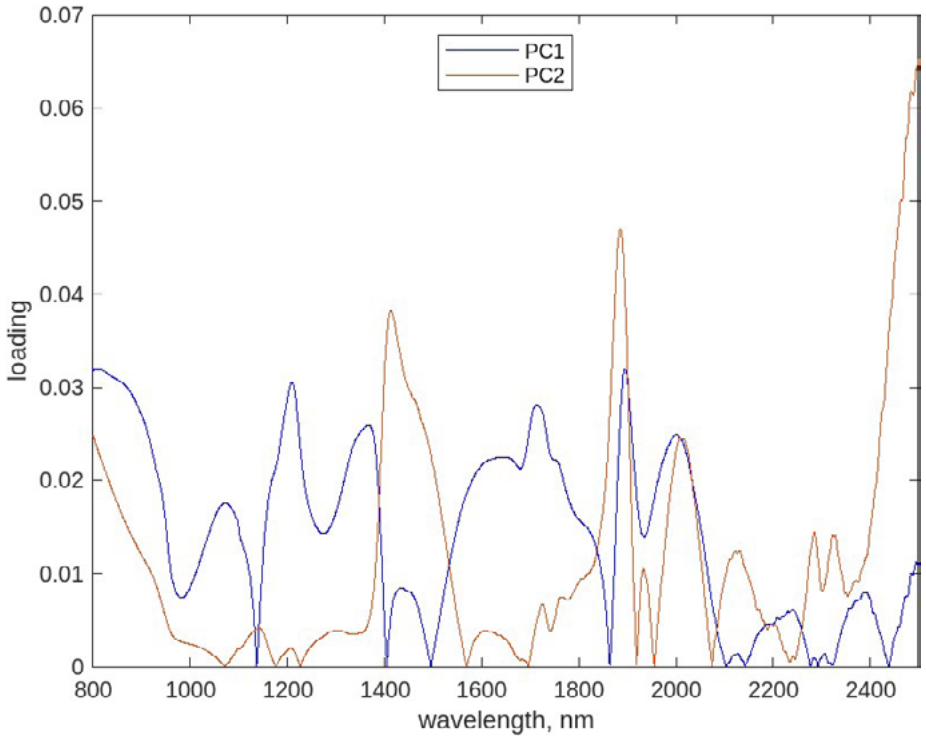
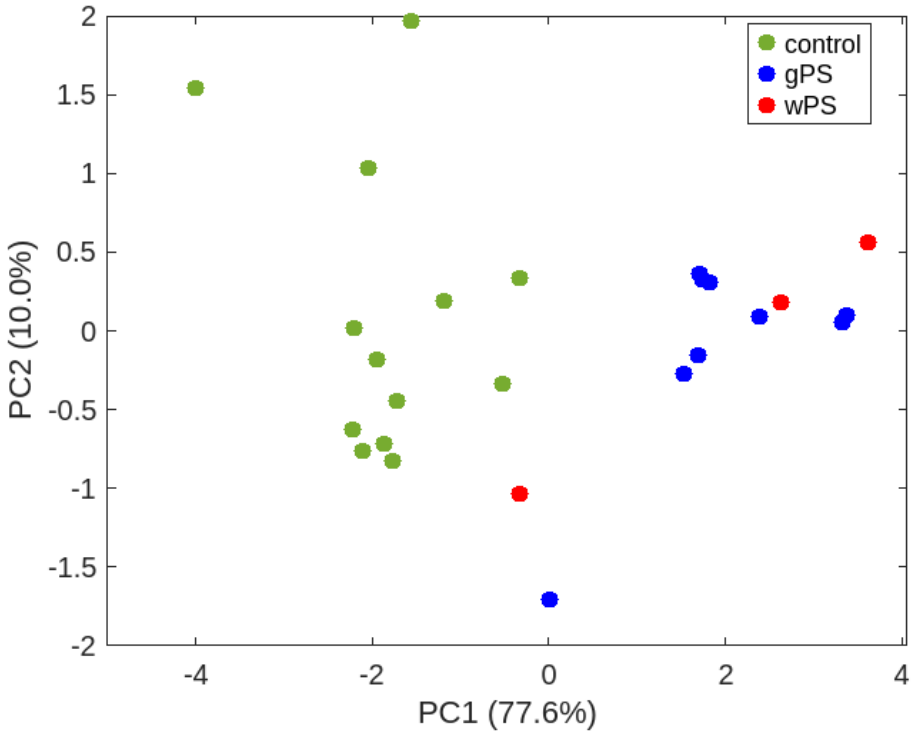


Figure 4 illustrates the absolute values of spectral loadings for the first two principal components. This plot explains which wavelengths contribute most to the variance within the datasets, and therefore, if a separation between the groups emerges, it indicates which wavelengths and hence chemical bonds cause the difference in the feed groups. The 1209 nm peak in the first principal component (PC1) is probably the second overtone of methylene C-H stretching, which can overlap with the peak of lipids at 1200 nm (Workman & Weyer, 2012). The peak at 1366 nm may be a C-H from aromatic hydrocarbons. The peak at 1633 nm may indicate C-H stretching in vinyl groups or C-H stretching in aromatic hydrocarbons caused by pollutant residues from the manufacturing process (Ciurczak et al., 2021). A peak at 1647 nm is the first overtone of C-H stretching of the double bond in the 1645-1675 nm range. A peak at 1894 nm may indicate vibrations of O-H hydrogen bonding

(Workman & Weyer, 2012). The peak observed in principal component 2 (PC2) at 1412 nm may be associated with aromatic bending in the C-H plane or methylene C-H, combined with branched aliphatic compounds as assumed contaminants. At 2008 nm, it may be an N-H or C-N combination band from primary amides (Workman & Weyer, 2012). The peaks were determined entirely based on the three literature sources cited (Workman & Weyer, 2012; Ciurczak et al., 2021; Kröncke & Benning, 2022) and are, therefore, assumptions and not conclusive. Further studies are required to determine the exact composition.



5. Figure: Scatterplot derived from the initial two principal components (PC1, PC2), control - mixture of carrot and flour; gPS - diet contained grey Styrofoam, wPS - diet contained white Styrofoam

Figure 5 represents the scatterplot derived from the initial two principal components (PC1 and PC2), showing a clear separation between the control group and the PS-fed groups. Principal component analysis is typically employed to reduce the dimensionality of a data set by summarising the data set with a smaller number of variables (Bartholomew, 2010), which enables us to efficiently run classification algorithms using only seven latent variables with practically the same outcome as with all 3400 original variables. In this instance, the initial principal component accounts for 77.6% of the variance in the data set, while the second principal component describes 10.0% of the variance, and the first three principal components collectively account for 94.9% of the data variance. The loading values corresponding to the wavelengths for the first two PCs are shown in **Figure 4**, in comparing this figure with the pre-processed averaged spectra the correspondence between the observed differences and the loading peaks are apparent. Figure 5 demonstrates that larvae nourished with a diet devoid of polystyrene can be discernibly differentiated from those fed a diet containing Styrofoam. This suggests the existence of a discernible discrepancy in the spectral data.

As previously mentioned (Chapter 2.3), the estimation was conducted by selecting the optimal model from the evaluated models. The Support Vector Machine (SVM) gave the best result, which exhibited an accuracy rate of 88% for three distinct feed types, indicating the model's overall performance. No misclassification of larvae was observed in the polystyrene-free food samples. However, the model results indicated some degree of uncertainty regarding the two polystyrene types. Further, run models discriminated between larvae fed with the three feed types with 76-84% accuracy.

Matlab 2019a software was used to run the models, with the two different Styrofoam feeds treated as a single feed. This resulted in the three feed types being reduced to two, comprising a conventional polystyrene-free and polystyrene-containing feed. Once more, the input variables were the pretreated spectral coefficients, while the estimated variables were the two feed types. In this instance, the linear discriminant analysis yielded 96% accuracy, with the linear support vector machine (SVM) model discriminating the samples with a marginally inferior accuracy of 92% compared to the previous case. However, the quadratic SVM and the cubic SVM produced 100% accuracy.

4. Conclusions

The rapid growth of the global population is resulting in a surge in demand for high biological value proteins, which is, in turn, leading to a corresponding increase in the production of plastic and plastic waste (Internet 1, OECD 2022). Research suggests that edible insects, like *Tenebrio molitor* larvae, could play a role in the European Commission's Circular Management Plan (Madau et al., 2020). Their intestinal tract hosts bacteria and enzymes capable of degrading hard-to-break-down plastics (Yang et al., 2015; Choi et al., 2022; Machona et al., 2022; Wang & Tang 2022; Nakatani et al., 2024).

This study aimed to find an effective method of confirming larval plastic consumption. Three diets were tested: a mixture of flour and carrot, white polystyrene packaging, and grey polystyrene with activated carbon.

The linear support vector machine (SVM) gave the best results, discriminating the groups with 88% accuracy and showing no misclassification of larvae fed the polystyrene-free substrate. Without distinguishing between the two types of polystyrene, two diet categories were created: with and without polystyrene. In this case, the linear SVM showed a separation efficiency of 92%, while the quadratic and cubic SVMs reached 100%.

The results demonstrate that, with the appropriate methodology, it is possible to differentiate between larvae that have been fed polystyrene and those that have been fed a diet that does not contain polystyrene with NIR spectroscopy. The spectra were analysed based on three existing literature sources (Workman&Weyer, 2012; Ciurczak et al., 2021; Kröncke & Benning, 2022). Therefore these results are not definitive. Further research is necessary to ascertain the complete picture of the precise composition in order to determine whether the presence or accumulation of undegraded microplastics in the larvae is responsible for the observed spectral differences.

5. References

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COMMISSION IMPLEMENTING REGULATION (EU) 2021/882 of 1 June 2021 authorising the placing on the market of dried Tenebrio molitor larva as a novel food under Regulation (EU) 2015/2283 of the European Parliament and of the Council, and amending Commission Implementing Regulation (EU) 2017/2470 https://eur-lex.europa.eu/legal-content/HU/TXT/?uri=CELEX:32021R0882

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Műanyaggal és hagyományos táptalajjal etetett Tenebrio molitor *lárvák megkülönböztetésének lehetőségei*

Kulcsszavak: *Tenebrio molitor,* műanyaghulladék, lisztféreg, körforgásos gazdaság, NIR (közeli infravörös spektroszkópia)

1. Összefoglalás

A globális népesség gyors növekedése növeli a kiváló minőségű biológiai fehérjék iránti keresletet, és hozzájárul a műanyaggyártás és a műanyaghulladékok növekedéséhez. Kutatások szerint bizonyos lárvák a bélrendszerükben található baktériumok és enzimek segítségével képesek lebontani a biológiai lebomlásnak ellenálló műanyagokat. A tanulmány célja egy ipari felhasználásra alkalmas mérési módszer kidolgozása a lárvák műanyagfogyasztásának kimutatására, amelyek három különböző táplálékot kaptak: liszt és sárgarépa keverékét (kontroll), fehér polisztirolt (wPs) és aktív szénnel dúsított szürke polisztirolt (gPS). A polisztirol (PS) mellett a második két csoport liszt és sárgarépa keverékét is kapta. A méréseket közeli infravörös spektroszkópiával végeztük, és az adatokat Matlab2019a szoftverrel elemeztük. A spektrumok előkezelését követően különböző osztályozási algoritmusokat alkalmaztunk a három csoport elkülönítésére. A lineáris SVM (Support Vector Machine) modell 88%-os pontossággal különítette el a három csoportot. A polisztirolmentes táplálékkal etetett lárvák pontosan azonosíthatók voltak, míg a kétféle polisztirollal etetett lárvák kevésbé voltak jól megkülönböztethetők. Az osztályozási módszereket két csoportra, polisztirolt tartalmazó és polisztirolmentes táplálékkal etetett lárvákra is teszteltük. Az eredmények azt mutatják, hogy a lineáris SVM 92%-os hatékonysággal működött. Ugyanakkor a kvadratikus SVM és a köbös SVM 100%-os hatékonyságot mutatott. Az eredmények azt mutatják, hogy a megfelelő modell alkalmazható a polisztirolt fogyasztó lárvák és a műanyagmentes táplálékot fogyasztó lárvák megkülönböztetésére. A megkülönböztetést előidéző alapvető mechanizmusok, legyen az a lárvák belében található lebomlatlan mikroműanyagok vagy a polisztirolból felhalmozódott egyéb anyagok, további vizsgálatot igényelnek.

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Nemzeti szabványosítási hírek

A következő felsorolásban szereplő szabványok megvásárolhatók vagy megrendelhetők az MSZT Szabványboltban (1082 Budapest VIII., Horváth Mihály tér 1., telefon: 456-6893, telefax: 456-6841, e-mail: kiado@mszt.hu; levélcím: Budapest 9., Pf. 24, 1450), illetve elektronikus formában beszerezhetők a www.mszt.hu/webaruhaz címen.

A nemzetközi/európai szabványokat bevezetjük magyar nyelven, valamint magyar nyelvű címoldallal és angol nyelvű tartalommal. A magyar nyelven bevezetett nemzetközi/európai szabványok esetén külön feltüntetjük a magyar nyelvű hozzáférést.

2024. szeptember – 2024. november hónapban bevezetett szabványok:

07.100.30 Élelmiszer-mikrobiológia

MSZ CEN ISO/TS 15213-3:2024 Az élelmiszerlánc mikrobiológiája. Horizontális módszer a *Clostridium* spp. kimutatására és számlálására. 3. rész: A *Clostridium perfringens* kimutatása (ISO/TS 15213-3:2024)

MSZ CEN ISO/TS 17728:2019 Az élelmiszerlánc mikrobiológiája. Mintavételi technikák az élelmiszertermékek és takarmányfélék mintáinak mikrobiológiai vizsgálatához (ISO/TS 17728:2015)

MSZ ISO 4832:2023 Élelmiszerek és takarmányok mikrobiológiája. Horizontális módszer a koliformok megszámlálására. Telepszámlálásos módszer – Az MSZ ISO 5541-1:1994 és az MSZ 3640-18:1979 helyett –

MSZ ISO 7251:2024 Élelmiszerek és takarmányok mikrobiológiája. Horizontális módszer a feltételezett *Escherichia coli* kimutatására és számlálására. A legvalószínűbb (élősejt)szám technikája

MSZ ISO 7251:2005/Amd 1:2024 Élelmiszerek és takarmányok mikrobiológiája. Horizontális módszer a feltételezett *Escherichia coli* kimutatására és számlálására. A legvalószínűbb (élősejt) szám technikája. 1. módosítás: Kiegészítés a tápközegek és reagensek teljesítményvizsgálatával – Az MSZ ISO 7251:2024 módosítása –

13.020.55 Bioalapú termékek

MSZ EN 17980:2024 Algák és algából készült termékek. Mintavétel. Irányelvek a mintavételi programok és mintavételi protokollok meghatározásához

13.060 Vízminőség

MSZ 6096:2024 Vízminőség. A kémiai oxigénigény meghatározása kálium-dikromátos módszerrel – Az MSZ 12750-21:1971 és az MSZ ISO 6060:1991 helyett –

MSZ EN 17892:2024 Vízminőség. Egyes per- és polifluor-alkil anyagok meghatározása ivóvízben. Folyadékkromatográfiás/tandem-tömegspektrometriás (LC-MS/MS) módszer

MSZ EN ISO 5667-3:2024 Vízminőség. Mintavétel. 3. rész: A vízminták tartósítása és kezelése (ISO 5667-3:2024) – Az MSZ EN ISO 5667-3:2018 helyett –

MSZ EN ISO 13165-1:2024 Vízminőség. Rádium-226. 1. rész: Vizsgálati módszer folyadékszcintillációs számlálóval (ISO 13165-1:2022) – Az MSZ EN ISO 13165-1:2020 helyett –

MSZ EN ISO 17294-1:2024 Vízminőség. Induktív csatolású plazma-tömegspektrometria (ICP-MS) alkalmazása. 1. rész: Általános követelmények (ISO 17294-1:2024) – Az MSZ EN ISO 17294-1:2007 helyett –

13.080 Talajminőség. Talajtan

[1] Magyar Szabványügyi Testület (MSZT)

MSZ EN ISO 18187:2024 Talajminőség. Kontaktvizsgálat szilárd mintákhoz az *Arthrobacter globiformis* dehidrogenáz-aktivitásával (ISO 18187:2024) – Az MSZ EN ISO 18187:2018 helyett –

MSZ EN ISO 18589-3:2024 A környezeti radioaktivitás mérése. Talaj. 3. rész: Gamma-sugárzó radionuklidok vizsgálati módszere gamma-spektrometriával (ISO 18589-3:2023) – Az MSZ EN ISO 18589-3:2018 helyett –

MSZ EN ISO 23611-2:2024 Talajminőség. Talajlakó gerinctelenek mintavétele. 2. rész: A mikroízeltlábúak (*Collembola* és *Acarina*) mintavétele és extrakciója (ISO 23611-2:2024) – Az MSZ EN ISO 23611-2:2012 helyett –

65 Mezőgazdaság

65.120 Takarmányanyagok

MSZ EN ISO 30024:2024 Takarmányok. A fitázaktivitás meghatározása (ISO 30024:2024) – Az MSZ EN ISO 30024:2010 helyett –

67 Élelmiszeripar

67.050 Élelmiszertermékek vizsgálatának és elemzésének általános módszerei

MSZ CEN/TS 15568:2007 Élelmiszerek. Analitikai módszerek a genetikailag módosított organizmusok és az ezeket tartalmazó termékek kimutatására. Mintavételi stratégiák

MSZ EN 17855:2024 Élelmiszerek. Minimális teljesítménykövetelmények a tej, tojás, földimogyoró, mogyoró, mandula, dió, kesudió, pekándió, brazil dió, pisztácia, makadámdió, búza, csillagfürt, szezám, mustár, szója, zeller, halak, puhatestűek és rákfélék mint élelmiszer-allergének mennyiségi mérésére

67.100 Tej és tejtermékek

MSZ ISO 6611:2023 Tej és tejtermékek. Az élesztő- és/vagy penészgombák telepképző egységeinek megszámlálása. Telepszámlálásos módszer 25 °C-on – Az MSZ ISO 6611:1993 helyett –

67.200 Étolajok és -zsírok. Olajmagvak

MSZ 15485-7:2024 Margarinok vizsgálata. 7. rész: A tartósítószer-tartalom meghatározása – Az MSZ 15485-7:1982 helyett –

MSZ EN ISO 662:2016 Állati és növényi zsírok és olajok. A nedvesség- és az illóanyag-tartalom meghatározása (ISO 662:2016) – Az MSZ EN ISO 662:2001 helyett –

MSZ EN ISO 3960:2017 Állati és növényi zsírok és olajok. A peroxidszám meghatározása. Jodometriás (vizuális) végpont-meghatározás (ISO 3960:2017) – Az MSZ EN ISO 3960:2010 helyett –

MSZ EN ISO 20122:2024 Növényi olajok. Az ásványolaj-eredetű telített szénhidrogének (MOSH) és aromás szénhidrogének (MOAH) meghatározása online csatolású, nagy hatékonyságú folyadékkromatográfiás, gázkromatográfiás, lángionizációs kimutatással (HPLC-GC-FID) történő vizsgálattal. Módszer az alsó mennyiségi meghatározási határértékre (ISO 20122:2024)

67.220 Fűszerek és ízesítők. Élelmiszer-adalékanyagok

MSZ EN ISO 7541:2021 Fűszerek és ízesítők. A paprika extrahálható színének spektrofotometriás meghatározása (ISO 7541:2020) – Az MSZ EN ISO 7541:2010 helyett –

MSZ ISO 6754:2024 Szárított kakukkfű (*Thymus vulgaris* L.). Előírás – Az MSZ 20067:1984 helyett –

MSZ ISO 7925:2024 Szárított oregánó (*Origanum vulgare* L.). Egész vagy őrölt levelek. Előírás – Az MSZ 20004:1984 helyett –

MSZ ISO 7926:2024 Szárított tárkony (*Artemisia dracunculus* Linnaeus). Előírás – Az MSZ 20021:1984 helyett –

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Review of national standardization

The following Hungarian standards are commercially available at MSZT (Hungarian Standards Institution, H-1082 Budapest, Horváth Mihály tér 1., phone: +36 1 456 6893, fax: +36 1 456 6841, e-mail: kiado@mszt.hu, postal address: H-1450 Budapest 9., Pf. 24) or online via website: www.mszt.hu/webaruhaz.

Published national standards from September 2024 to November 2024

07.100.30 Food microbiology

MSZ CEN ISO/TS 15213-3:2024 Microbiology of the food chain. Horizontal method for the detection and enumeration of *Clostridium* spp. Part 3: Detection of *Clostridium perfringens* (ISO/TS 15213-3:2024)

MSZ CEN ISO/TS 17728:2019 Microbiology of the food chain. Sampling techniques for microbiological analysis of food and feed samples (ISO/TS 17728:2015)

MSZ ISO 4832:2023 Microbiology of food and animal feed stuffs. Horizontal method for the enumeration of coliforms. Colony-count technique – which has replaced the MSZ ISO 5541-1:1994 and the MSZ 3640-18:1979 –

MSZ ISO 7251:2024 Microbiology of food and animal feed stuffs. Horizontal method for the detection and enumeration of presumptive *Escherichia coli*. Most probable number technique

MSZ ISO 7251:2005/Amd 1:2024 Microbiology of food and animal feed stuffs. Horizontal method for the detection and enumeration of presumptive *Escherichia coli*. Most probable number technique. Amendment 1: Inclusion of performance testing of culture media and reagents – which is amendment of MSZ ISO 7251:2024 –

13.020.55 Biobased products

MSZ EN 17980:2024 Algae and algae products. Sampling. Guidelines for the definition of sampling programs and sampling protocols

13.060 Water quality

MSZ 6096:2024 Water quality. Determination of the chemical oxygen demand by potassium dichromate method – which has replaced the MSZ 12750-21:1971 and the MSZ ISO 6060:1991 –

MSZ EN 17892:2024 Water quality. Determination of selected per- and polyfluoroalkyl substances in drinking water. Method using liquid chromatography/tandem-mass spectrometry (LC-MS/MS)

MSZ EN ISO 5667-3:2024 Water quality. Sampling. Part 3: Preservation and handling of water samples (ISO 5667-3:2024) – which has replaced the MSZ EN ISO 5667-3:2018 –

MSZ EN ISO 13165-1:2024 Water quality. Radium-226. Part 1: Test method using liquid scintillation counting (ISO 13165-1:2022) – which has replaced the MSZ EN ISO 13165-1:2020 –

MSZ EN ISO 17294-1:2024 Water quality. Application of inductively coupled plasma mass spectrometry (ICP-MS). Part 1: General requirements (ISO 17294-1:2024) – which has replaced the MSZ EN ISO 17294-1:2007 –

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MSZ EN ISO 23611-2:2024 Soil quality. Sampling of soil invertebrates. Part 2: Sampling and extraction of micro-arthropods (*Collembola* and *Acarina*) (ISO 23611-2:2024) – which has replaced the MSZ EN ISO 23611-2:2012 –

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MSZ EN ISO 662:2016 Animal and vegetable fats and oils. Determination of moisture and volatile matter content (ISO 662:2016) – which has replaced the MSZ EN ISO 662:2001 –

MSZ EN ISO 3960:2017 Animal and vegetable fats and oils. Determination of peroxide value. Iodometric (visual) endpoint determination (ISO 3960:2017) – which has replaced the MSZ EN ISO 3960:2010 –

MSZ EN ISO 20122:2024 Vegetable oils. Determination of mineral oil saturated hydrocarbons (MOSH) and mineral oil aromatic hydrocarbons (MOAH) with online-coupled high performance liquid chromatography-gas chromatography-flame ionization detection (HPLC-GC-FID) analysis. Method for low limit of quantification (ISO 20122:2024)

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