LAPORAN AKHIR
PENELITIAN FUNDAMENTAL - REGULER
TAHUN ANGGARAN 2024

Studi Pengaruh Kondisi Proses Pengeringan Semprot terhadap Karakteristik Bubuk VCO (Virgin Coconut Oil) Bersalut Inulin

UBAYA

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TEKNIK KIMIA
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PROTEKSI ISI LAPORAN AKHIR PENELITIAN FUNDAMENTAL - REGULER

LAPORAN AKHIR 2024

Rencana Pelaksanaan Penelitian Fundamental - Reguler: tahun 2024 s.d. tahun 2024

1. JUDUL PENELITIAN

Studi Pengaruh Kondisi Proses Pengeringan Semprot terhadap Karakteristik Bubuk VCO (Virgin Coconut Oil) Bersalut Inulin

Bidang Fokus	Tema	Topik (jika ada)	Prioritas Riset
Pangan	Teknologi pascapanen dan rekayasa teknologi pengolahan pangan	Penguatan agroindustri berbahan baku sumber daya lokal	Kemandirian Kesehatan

Rumpun Ilmu Level 1	Rumpun Ilmu Level 2	Rumpun Ilmu Level 3
ILMU TEKNIK	ILMU KETEKNIKAN INDUSTRI	Teknik Kimia

Skema Penelitian	Strata (Dasar/Terapan/ Pengembangan)	Nilai SBK	Target Akhir TKT	Lama Kegiatan
Penelitian Fundamental - Reguler	Riset Dasar	150.000.000	3	1 Tahun

2. IDENTITAS PENGUSUL

Nama, Peran	Jenis	Program Studi/Bagian	Bidang Tugas	ID Sinta
LANNY SAPEI 0425017801 Ketua Pengusul Universitas Surabaya	Dosen	Teknik Kimia	-Mendesain percobaan pengeringan semprot untuk pembuatan bubuk VCO dengan menggunakan inulin sebagai bahan pengisi -Mengkoordinasi dan memonitor percobaan -Trouble shooting selama pelaksanaan eksperimen -Mengevaluasi dan menginterpretasi data percobaan -Membuat laporan dan publikasi	5981633
RUDY AGUSTRIYANTO 0709087201 Anggota Universitas Surabaya	Dosen	Teknik Kimia	-Membantu pelaksanaan karakterisasi bubuk VCO dengan berbagai metode -Membantu analisis data -Membantu pembuatan laporan dan publikasi	257134
PUTU DODDY SUTRISNA 0701077603 Anggota Universitas Surabaya	Dosen	Teknik Kimia	-Membantu mendesain eksperimen -Membantu interpretasi data hasil percobaan -Membantu pembuatan laporan dan publikasi	6016571

3. MITRA KERJASAMA PENELITIAN (Jika Ada)

Pelaksanaan penelitian dapat melibatkan mitra kerjasama yaitu mitra kerjasama dalam melaksanakan penelitian, mitra sebagai calon pengguna hasil penelitian, atau mitra investor

Mitra	Nama Mitra	Dana

4. LUARAN DAN TARGET CAPAIAN

Luaran Wajib

Tahun Luaran	Kategori Luaran	Jenis Luaran	Status target capaian	Keterangan
1	Artikel di Jurnal	Artikel di Jurnal Bereputasi Internasional	Accepted/Published	https://journals.sagepub.com/home/FST; Food Science and Technology International

5. ANGGARAN

Rencana Anggaran Biaya penelitian mengacu pada PMK dan buku Panduan Penelitian dan Pengabdian kepada Masyarakat yang berlaku.

Total RAB 1 Tahun Rp121.570.000,00

Tahun 1 Total Rp121.570.000,00

Kelompok	Komponen	Item	Satuan	Vol.	Biaya Satuan	Total
Pengumpulan Data	Transport	Dalam kota Surabaya PP	OK (kali)	12	170.000	2.040.000
Analisis Data	HR Pengolah Data	Data hasil eksperiment	P (penelitian)	1	1.540.000	1.540.000
Pengumpulan Data	Uang Harian	4 orang, 2 hari, Semarang	OH	8	410.000	3.280.000
Bahan	Barang Persediaan	Motor Pengaduk IKA	Unit	1	17.000.000	17.000.000
Bahan	Barang Persediaan	Kantung pouch	Unit	50	7.000	350.000
Bahan	Bahan Penelitian (Habis Pakai)	Maltodekstrin 1 kg, DE 20	Unit	1	150.000	150.000
Bahan	Barang Persediaan	Impeller SS	Unit	3	250.000	750.000
Analisis Data	Biaya analisis sampel	Texture Analyzer (UKWMS)	Unit	15	100.000	1.500.000
Analisis Data	Biaya analisis sampel	SEM (ITS)	Unit	8	450.000	3.600.000
Pengumpulan Data	HR Pembantu Peneliti	Pembantu peneliti 2	OJ	200	25.000	5.000.000
Bahan	Bahan Penelitian (Habis Pakai)	Tween 80 Merck 500 ml	Unit	1	1.050.000	1.050.000
Bahan	Bahan Penelitian (Habis Pakai)	filter spray dryer	Unit	1	1.500.000	1.500.000
Pengumpulan Data	Uang Harian	6 orang, 3 hari	OH	18	160.000	2.880.000
Analisis Data	Biaya analisis sampel	Viskositas	Unit	5	250.000	1.250.000
Pelaporan Hasil Penelitian dan Luaran Wajib	Biaya Publikasi artikel di Jurnal Bereputasi Interasional	Food Science and Technology International	Paket	1	12.000.000	12.000.000
Bahan	Bahan Penelitian (Habis Pakai)	VCO 500 ml	Unit	3	120.000	360.000
Bahan	Bahan Penelitian (Habis Pakai)	Span 80 Sigma Aldrich 500 ml	Unit	1	6.500.000	6.500.000
Bahan	Barang Persediaan	Heater Belt Silicon Foil 200 W	Unit	1	1.500.000	1.500.000
Bahan	Barang	Reaktor gelas leher 3,	Unit	1	2.000.000	2.000.000

Kelompok	Komponen	Item	Satuan	Vol.	Biaya Satuan	Total
	Persediaan	500 ml +Clamp				
Bahan	Barang Persediaan	Pan Ayakan	Unit	1	2.500.000	2.500.000
Analisis Data	Biaya analisis sampel	GPC (Undip)	Unit	5	600.000	3.000.000
Bahan	Bahan Penelitian (Habis Pakai)	NaCl Merck 1 kg	Unit	1	1.800.000	1.800.000
Bahan	Barang Persediaan	Desikator ID 24 cm	Unit	1	1.900.000	1.900.000
Bahan	Bahan Penelitian (Habis Pakai)	PgPr Palsgaard 4120	Unit	1	5.000.000	5.000.000
Pelaporan Hasil Penelitian dan Luaran Wajib	Uang harian rapat di dalam kantor	Rapat koordinasi, 4 orang, 10 kali	OH	40	50.000	2.000.000
Pengumpulan Data	Uang harian rapat di dalam kantor	Rapat koordinasi, 4 orang, 10 kali	OH	40	50.000	2.000.000
Analisis Data	Biaya analisis sampel	Partikel Size Analyzer Zeta (Undip)	Unit	5	300.000	1.500.000
Analisis Data	Biaya analisis sampel	FTIR (ITS)	Unit	20	150.000	3.000.000
Bahan	Barang Persediaan	Botol/ Wadah Sampel	Unit	1	250.000	250.000
Pengumpulan Data	Biaya konsumsi	Rapat koordinasi, 4 orang, 10 kali	OH	40	48.000	1.920.000
Bahan	Barang Persediaan	Ember /bak /container	Unit	5	50.000	250.000
Pengumpulan Data	HR Pembantu Peneliti	Pembantu peneliti 1	OJ	220	25.000	5.500.000
Bahan	Barang Persediaan	Corong Buchner (filtrasi)	Unit	1	1.500.000	1.500.000
Bahan	ATK	Adaptor dan keyboard protector	Paket	1	330.000	330.000
Bahan	ATK	Buku paperline	Paket	3	25.000	75.000
Bahan	Bahan Penelitian (Habis Pakai)	Beaker glass 1 L pyrex	Unit	6	125.000	750.000
Bahan	Barang Persediaan	Beaker glass 2 L pyrex	Unit	6	225.000	1.350.000
Pelaporan Hasil Penelitian dan Luaran Wajib	Biaya konsumsi rapat	Rapat koordinasi, 4 orang, 10 kali	OH	40	48.000	1.920.000
Bahan	ATK	CD Drive Eksternal	Paket	1	350.000	350.000
Bahan	Barang Persediaan	Ayakan 100 mesh	Unit	1	3.750.000	3.750.000
Pengumpulan Data	HR Pembantu Lapangan	Pembantu lapangan 1	OH	51	80.000	4.080.000
Bahan	Barang Persediaan	Toples Kedap Lock 'n Lock 500 gr	Unit	5	100.000	500.000
Bahan	ATK	Tinta printer	Paket	2	130.000	260.000
Bahan	Bahan Penelitian (Habis Pakai)	Tween 20 Merck 500 ml	Unit	1	900.000	900.000
Bahan	ATK	Bollpoint	Paket	1	25.000	25.000
Bahan	Barang Persediaan	Kondensor bola	Unit	5	500.000	2.500.000
Bahan	Bahan	Dikalium Fosfat Merck	Unit	1	850.000	850.000

Kelompok	Komponen	Item	Satuan	Vol.	Biaya Satuan	Total
	Penelitian (Habis Pakai)	250 g				
Bahan	Bahan Penelitian (Habis Pakai)	silica gel blue teknis 1 kg	Unit	1	150.000	150.000
Analisis Data	Biaya analisis sampel	XRD (ITS)	Unit	5	250.000	1.250.000
Bahan	Bahan Penelitian (Habis Pakai)	KCl Merck 1 kg	Unit	1	960.000	960.000
Bahan	Bahan Penelitian (Habis Pakai)	KOH p.a Merck 1 kg	Unit	1	500.000	500.000
Pengumpulan Data	Penginapan	4 orang, 1 malam, Undip	OH	4	700.000	2.800.000
Bahan	Barang Persediaan	Botol pengamatan emulsi	Unit	10	60.000	600.000
Pengumpulan Data	Tiket	Kereta, surabaya-semarang PP	OK (kali)	4	300.000	1.200.000
Bahan	ATK	Kertas HVS ukuran A4 (rim)	Paket	2	50.000	100.000

*. KEMAJUAN PENELITIAN

A. RINGKASAN

Kesadaran masyarakat akan pentingnya mengkonsumsi makanan sehat semakin meningkat. VCO memiliki kandungan antioksidan yang tinggi serta sifat antimikroba dan antivirus sehingga dapat digunakan untuk pengobatan dan peningkatan imunitas tubuh [1]. Inulin merupakan serat makanan dan prebiotik yang sangat berguna untuk pencernaan dan kesehatan tubuh [2]. VCO yang dienkapsulasi menggunakan inulin sebagai bahan penyalut berpotensi digunakan sebagai pengganti susu/ santan dan dapat digunakan sebagai ingredient untuk beragam produk makanan dan minuman fungsional. Emulsi VCO dalam air, oil-in-water (O/W) yang mengandung inulin dikeringkan dengan alat spray dryer/ pengering semprot untuk menghasilkan bubuk VCO. Produk bubuk VCO memiliki masa simpan yang jauh lebih lama dibandingkan produk emulsi cair.

Penelitian ini bertujuan untuk memperoleh bubuk VCO bersalut inulin dengan yield yang tinggi serta karakteristik yang diharapkan seperti free flowing dan tidak menggumpal. Kandungan total solid (%TS) umpan emulsi dan kondisi proses pengeringan semprot, antara lain: laju alir umpan, tekanan nozzle, temperatur udara pengering, dan laju alir udara pengering akan dipelajari pengaruhnya terhadap yield dan karakteristik produk bubuk VCO yang dihasilkan.

Tahapan metode penelitian mencakup penyiapan umpan emulsi O/W melalui proses emulsifikasi minyak VCO dan bahan tambahan lain seperti Na-caseinate, penstabil, dan pengemulsi dalam fasa air yang mengandung inulin menggunakan rotor-stator homogenizer. Emulsi O/W yang dihasilkan lebih lanjut disonikasi untuk mengecilkan ukuran minyak fasa terdispersi. Umpan emulsi O/W kemudian dikeringkan pada berbagai kondisi proses pengeringan. Yield serta karakteristik bubuk VCO bersalut inulin akan dipelajari secara komprehensif.

Luaran dari hasil penelitian ini berupa jurnal internasional bereputasi Q1 (Applied Food Research) dengan status “minor revision” dan prototype produk berupa bubuk VCO bersalut inulin dengan TKT 3. Dari hasil penelitian diperoleh parameter proses terbaik selama pengeringan semprot, antara lain: total solid 50%, laju alir umpan 5 ml/ mnt, laju aspirasi 100%, tekanan udara pada nozzle 1 bar, dan temperatur udara pengering 150°C.

B. KATA KUNCI

bubuk VCO; emulsi O/W; inulin; temperatur pengeringan; pengeringan semprot

Pengisian poin C sampai dengan poin H mengikuti template berikut dan tidak dibatasi jumlah kata atau halaman namun disarankan seringkas mungkin. Dilarang menghapus/memodifikasi template ataupun menghapus penjelasan di setiap poin.

C. **HASIL PELAKSANAAN PENELITIAN:** Tuliskan secara ringkas hasil pelaksanaan penelitian yang telah dicapai sesuai tahun pelaksanaan penelitian. Penyajian meliputi data, hasil analisis, dan capaian luaran (wajib dan atau tambahan). Seluruh hasil atau capaian yang dilaporkan harus berkaitan dengan tahapan pelaksanaan penelitian sebagaimana direncanakan pada proposal. Penyajian data dapat berupa gambar, tabel, grafik, dan sejenisnya, serta analisis didukung dengan sumber pustaka primer yang relevan dan terkini.

Pada penelitian ini akan dikaji terkait optimalisasi proses pengeringan emulsi O/W menggunakan spray dryer, emulsi O/W digunakan memiliki komposisi antara lain: Inulin 61,5%; natrium kaseinat 2,5%; GMS 1%, VCO 32%; dikalium fosfat 2,5%; silika 0,5%. Emulsi O/W kemudian akan dikeringkan menggunakan spray dryer Buchi B-290 untuk menghasilkan bubuk krimer. Pada tahap pertama akan diakukan optimasi proses pengeringan spray dryer antara lain: suhu inlet udara, laju alir udara pengering, tekanan udara nozzle, laju alir umpan. Variasi parameter pertama adalah suhu inlet udara, sedangkan parameter lainnya ditetapkan (laju alir umpan 5 ml/min, aspirator 100%, tekanan 1 bar). Setelah diketahui hasil terbaik parameter suhu inlet udara pengering, tahap selanjutnya melakukan variasi pada aspirator untuk mengetahui pengaruh aspirator terhadap hasil bubuk krimer, dan parameter lainnya ditetapkan (laju alir umpan 5 ml/min, tekanan 1 bar, dan suhu inlet udara terbaik). Kemudian setelah didapatkan % aspirator terbaik, maka selanjutnya melakukan variasi tekanan dan parameter lainnya ditetapkan (laju alir udara umpan 5 ml/min, aspirator terbaik, suhu inlet udara terbaik). Pada tahap terakhir penentuan kondisi parameter optimasi optimum spray dryer, dilakukan variasi pada laju alir umpan dan parameter lainnya ditetapkan pada kondisi terbaiknya.

Tahap kedua, akan dilakukan variasi total solid (45, 50, 55) untuk jenis filler inulin, untuk mengetahui kondisi emulsi yang terbaik untuk parameter optimum spray dryer. Setelah didapatkan hasil optimum pada total solid terbaik emulsinya. Karakterisasi bubuk krimer meliputi *yield*, *moisture balance*, *bulk density*, *tapped density*, pH, uji higroskopisitas, uji *wettability*. Karakterisasi bubuk krimer dilakukan untuk mempelajari efisiensi proses pengeringan di spray dryer. Uji SEM dilakukan pada pemvariasian suhu inlet udara dan total solid untuk mempelajari karakteristik bubuk.

Seluruh variasi proses yang dilakukan pada percobaan di tahap satu dan tahap kedua dapat dilihat pada **Tabel C.1** dengan kode sampel, huruf pertama merupakan jenis variasi (T (suhu inlet udara), A (laju alir udara), P (tekanan udara nozzle), F (laju alir umpan), TS (total solid), kemudian diikuti oleh dua angka pertama yang menandakan variasi total solid, dan angka sisanya merupakan variasi parameter sesuai kode pada huruf pertamanya.

Tabel C.1 Parameter *Spray Dryer*

Kode Sampel	**Suhu *inlet* udara pengering (ºC)**	**Laju Umpan (ml/min)**	**Aspirator %**	**Tekanan**	***Jenis Filler***	***Total Solid %***
T50180	180	5	100	55mm	Inulin	50
T50150	150	5	100	55mm	Inulin	50
T50130	130	5	100	55mm	Inulin	50
T50110	110	5	100	55mm	Inulin	50
A5080	150	5	80	55mm	Inulin	50
P5065	150	5	100	65mm	Inulin	50
F5008	150	8	100	55mm	Inulin	50
TS45	150	5	100	55mm	Inulin	45
TS55	150	5	100	55 mm	Inulin	55

Tabel C.2 Karakteristik Bubuk Krimer

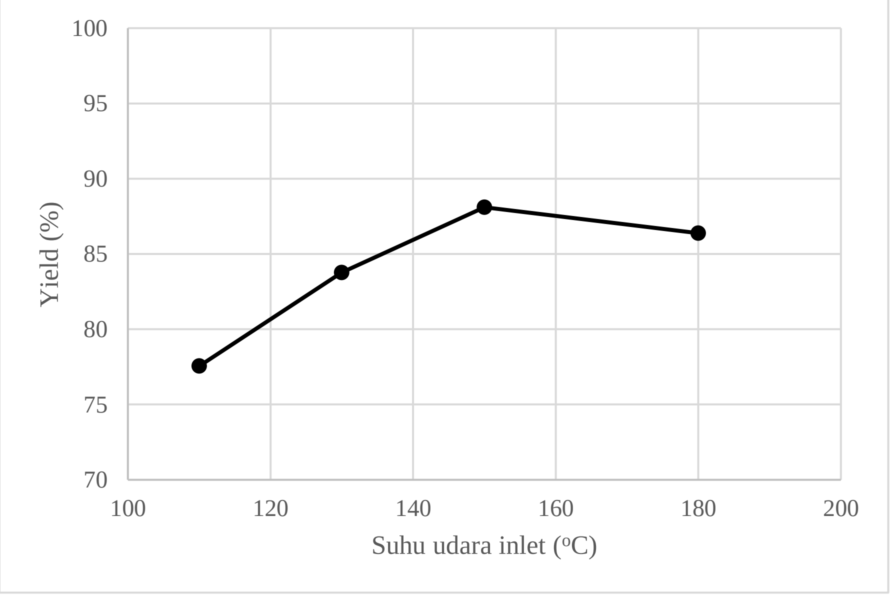
Kode Sampel	Yield Overall	Moisture %	Densitas Unttapped (g/ml)	Densitas Tapped (g/ml)	pH	Wettability waktu (menit)	Ukuran Partikel Rata-rata (µm)
T50180	86,38%	3,0%	0,3714	0,4776	7,662	6.500	474,45
T50150	88,10%	2,9%	0,4351	0,5559	7,873	5.016	281,84
T50130	83,76%	3,3%	0,4173	0,5272	7,797	4.900	165,88
T50110	77,55%	3,9%	0,4668	0,5735	7,765	4.616	200,60
A5080	87,50%	3,2%	0,4320	0,5457	7,839	4.950	315,72
P5065	85,65%	3,3%	0,4438	0,5794	7,725	4.800	201,33
F5008	86,01%	3,5%	0,4170	0,5267	7,726	4.916	295,29
TS45	83,23%	3,3%	0,4349	0,5557	7,683	4.783	210,64
TS55	77,67%	3,2%	0,4359	0,5897	7,713	4.866	187,54

Pada **Tabel C.2** dapat dilihat hasil karakteristik sampel yang diperoleh dari seluruh percobaan pada tahap 1 dan tahap 2. Dari tabel tersebut hasil karakterisasi bubuk krimer terhadap pH berada di rentang 7 – 8, merupakan pH yang cukup netral dan masih memenuhi standar SNI 01-2891-1992 dimana pH larutan standar untuk produk krimer berada pada rentang 6 – 9, sehingga hasil karakterisasi pH tidak akan di bahas pada sub-bab berikutnya. Hasil pembahasan pada percobaan pada tahap 1 dan tahap 2 akan disajikan pada masing – masing sub-bab di bawah ini.

C.1 Pengaruh Suhu Inlet Udara Pengering terhadap Karakteristik Bubuk Krimer

Pada tahap awal penelitian, pengaruh suhu *inlet* udara pada proses *Spray Dryer* telah dilakukan. Suhu inlet udara pengering divariasikan T50110 (110°), T50130 (130°), T50150 (150°), T50180 (180°) sedangkan parameter operasi ditetapkan (laju alir umpan 5 ml/min, aspirator 100%, tekanan 1 bar). Hasil *spray dryer* yang didapat kemudian dilakukan karakterisasi, yang akan dibahas lebih detail pada sub-bab selanjutnya.

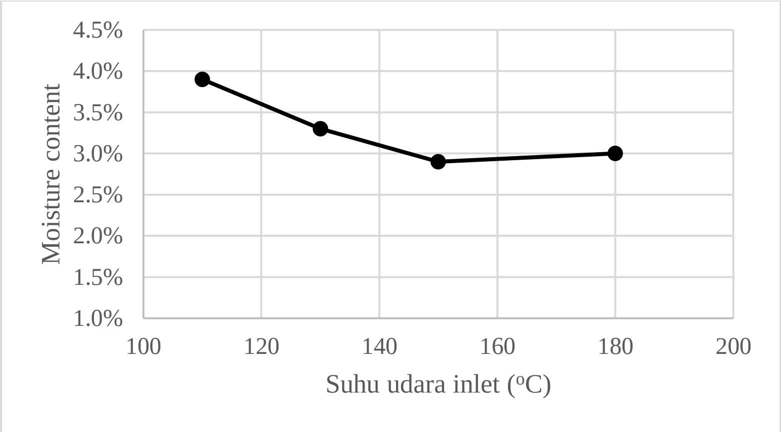
C.1.1 Pengaruh Suhu Inlet udara terhadap Yield serbuk krimer



Gambar C.1 Pengaruh Suhu Inlet udara terhadap *Yield*bubuk krimer

Pada **Gambar C.1** dapat dilihat pengaruh suhu inlet terhadap yield dimana, terjadi tren peningkatan yield akibat peningkatan suhu inlet udara. Pada suhu *inlet* udara 110 °C hingga 150 °C, *yield* bubuk yang didapatkan semakin meningkat, akan tetapi pada suhu *inlet* udara 180 °C *yield* menurun lagi. Penurunan *yield* bubuk pada temperatur yang terlalu tinggi dapat disebabkan oleh gelatinisasi dari partikel bubuk. Oleh karena itu dapat disimpulkan bahwa terdapat suhu *inlet* udara yang terbaik (150 °C) untuk mendapatkan *yield* bubuk produk yang tidak lengket pada dinding *chamber*.

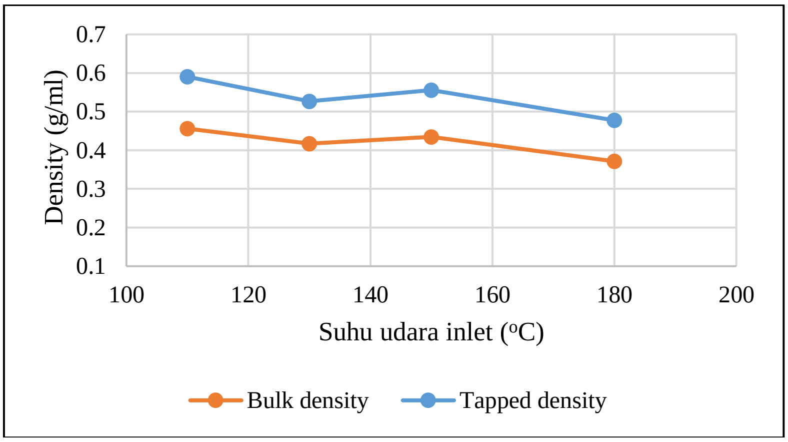
C.1.2 Pengaruh Suhu Inlet udara terhadap Moisture Content bubuk krimer



Gambar C.2 Pengaruh Suhu Inlet udara terhadap *Moisture Content*bubuk krimer

Pada **Gambar C.2** pengaruh suhu inlet terhadap moisture content menunjukkan tren penurunan moisture content yang diakibatkan adanya peningkatan suhu inlet. Hasil tersebut serupa dengan penelitian yang dilakukan oleh Abdullah et.al. [1], di mana *moisture content* bubuk hasil *spray drying* yang didapat menunjukan dimana dengan meningkatnya suhu *inlet* spray drying, *moisture content* menurun. *Moisture content* menurun karena suhu *inlet* udara yang lebih panas meningkatkan perpindahan dan panas, dengan demikian dapat menjadi *driving force* yang besar pada penghilangan air [2]. *Moisture content* yang rendah penting untuk menghindari bubuk dari kelengketan [3]. Oleh karena itu *moisture content* yang tinggi perlu dihindari supaya kelengketan tidak terjadi pada alat *spray dryer*. *Moisture content* pada suhu 180 °C naik lagi karena adanya crust dimana pengeringan yang terlalu cepat menyebabkan uap air terperangkap.

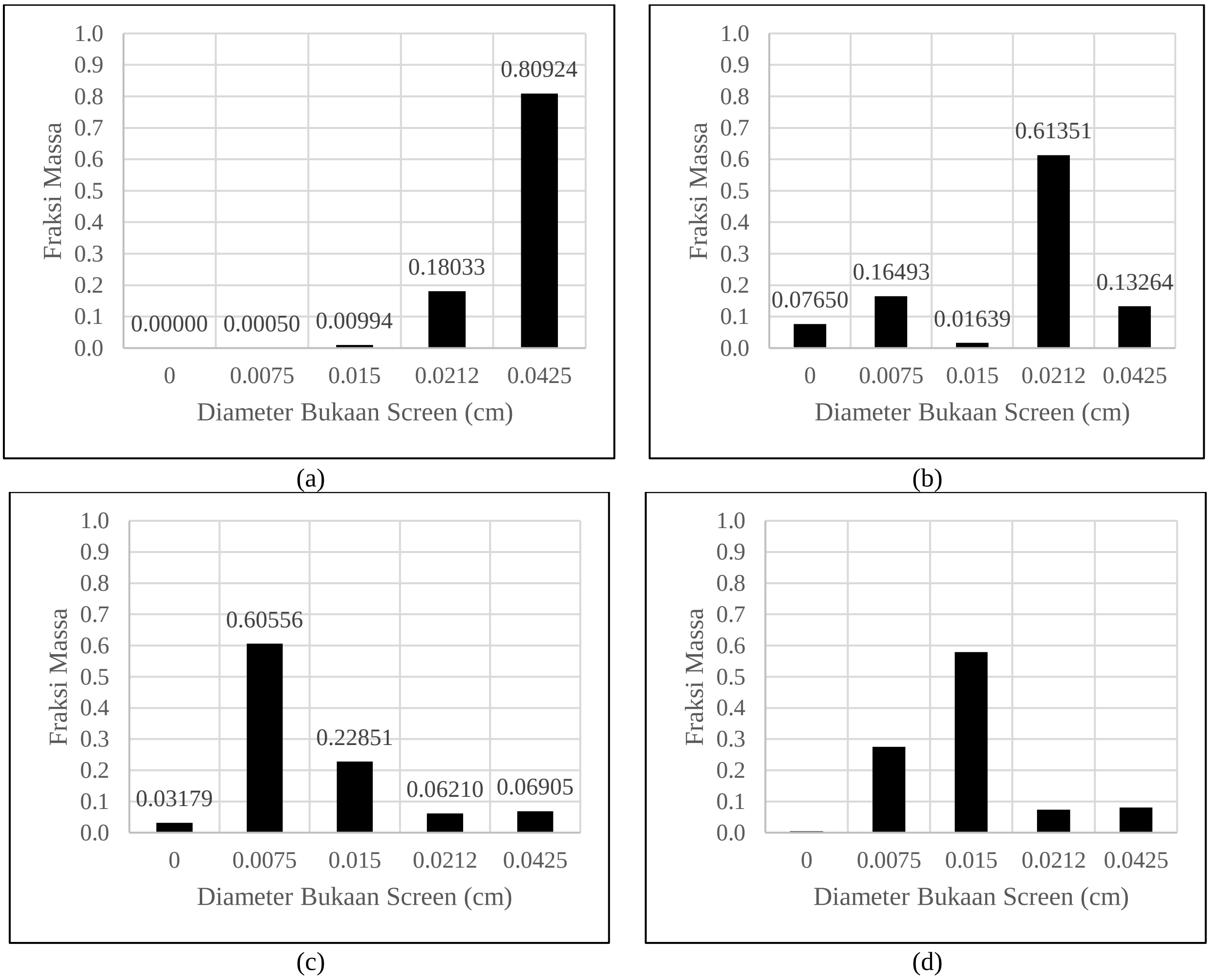
C.1.3 Pengaruh Suhu Inlet udara terhadap Bulk Density dan Tapped Density bubuk krimer



Gambar C.3 Pengaruh Suhu Inlet udara terhadap *Bulk Density* dan *Tapped Density* bubuk krimer

Pada **Gambar C.3** pengaruh suhu inlet terhadap bulk density dan tapped density. Bulk density mengukur massa bahan per unit volume tanpa pengompresan sedikit pun. Sedangkan tapped density adalah kepadatan bahan setelah dilakukan pengocokan (tapping) untuk memastikan adanya interaksi antar partikel bahan. Proses pengocokan ini menciptakan packings antar partikel yang lebih rapat dan menyebabkan volume total bahan menjadi lebih kecil.Bulk density dan tapped density mengalami penurunan seiring dengan meningkatnya suhu inlet udara. Hal tersebut disebabkan oleh udara terperangkap di *dalam* partikel pada suhu *inlet* udara yang tinggi sehingga mengurangi *bulk density* [4]. Tapped density adalah kepadatan bahan setelah dilakukan pengocokan (tapping) untuk memastikan adanya interaksi antar partikel bahan. Proses pengocokan ini menciptakan packings antar partikel yang lebih rapat dan menyebabkan volume total bahan menjadi lebih kecil. Hal ini didukung oleh penelitian Abdullah et.al. [1] yang menunjukkan hasil yang serupa yaitu bulk density cenderung memiliki tren yang menurun). Pada suhu 180ºC dapat dilihat pada hasil SEM bahwa banyak partikel yang terjadi porous dimana pori-pori pecah akibat adanya tekanan internal uap air pada saat penyimpanan, sehingga densitas turun drastis.

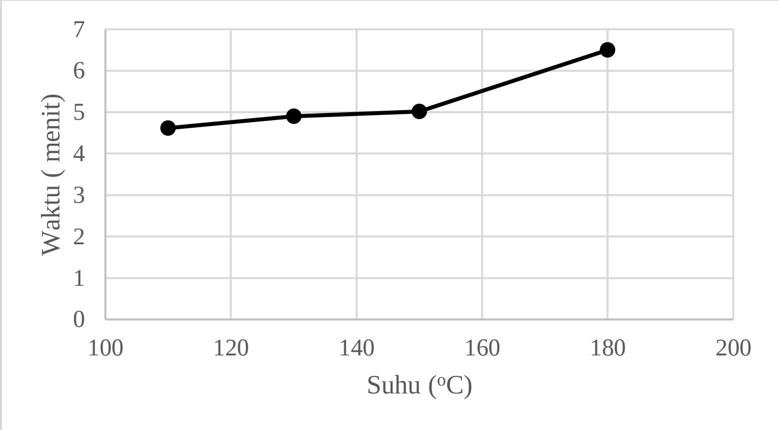
C.1.4 Pengaruh Suhu Inlet udara terhadap Size Distribution bubuk krimer



Gambar C.4 Pengaruh Suhu Inlet udara terhadap *Size Distribution* bubuk krimer ; (a) Suhu inlet udara 180 ºC, (b) Suhu inlet udara 150 ºC, (c) Suhu inlet udara 130 ºC,(d) Suhu inlet udara 110 ºC

Dari **Gambar C.4**, dapat dihitung *mean diameter* bubuk. Pada suhu *inlet* udara pada 180 ºC (T50180) diperoleh *mean diameter* bubuk sebesar ukuran 0,0474 cm, pada 150 ºC (T50150) diperoleh 0,0288 cm, pada 130 ºC (T50130) diperoleh 0,0166 cm, dan pada 110 ºC (T50110) diperoleh 0,021 cm. Hal tersebut bertentangan pada penelitian yang dilakukan Salimi et.al. [5]. Ukuran *mean diameter* meningkat dengan meningkatnya suhu *inlet* udara. Ukuran mean diameter pada suhu *inlet* udara 110ºC (T50110) yang lebih besar daripada ukuran mean diameter pada suhu *inlet* udara 130ºC (T50130) kemungkinan disebabkan aglomerasi dari partikel bubuk dimana, ukuran bubuk menjadi semakin besar. Terjadiya aglomerasi pada suhu rendah dikarenakan suhu inlet udara yang rendah pada spray dryer dapat menyebabkan kondensasi uap air di dalam ruang kering, yang dapat menyebabkan aglomerasi partikel dari emulsi O/W. Kondensasi uap air dapat menyebabkan partikel emulsi O/W untuk melekat satu sama lain, yang menyebabkan aglomerasi. Selain itu, suhu inlet yang rendah juga dapat menyebabkan partikel emulsi O/W untuk mengering dengan lambat, yang dapat menyebabkan partikel untuk melekat satu sama lain selama proses pengeringan.

C.1.5 Pengaruh Suhu Inlet udara terhadap Wettability bubuk krimer



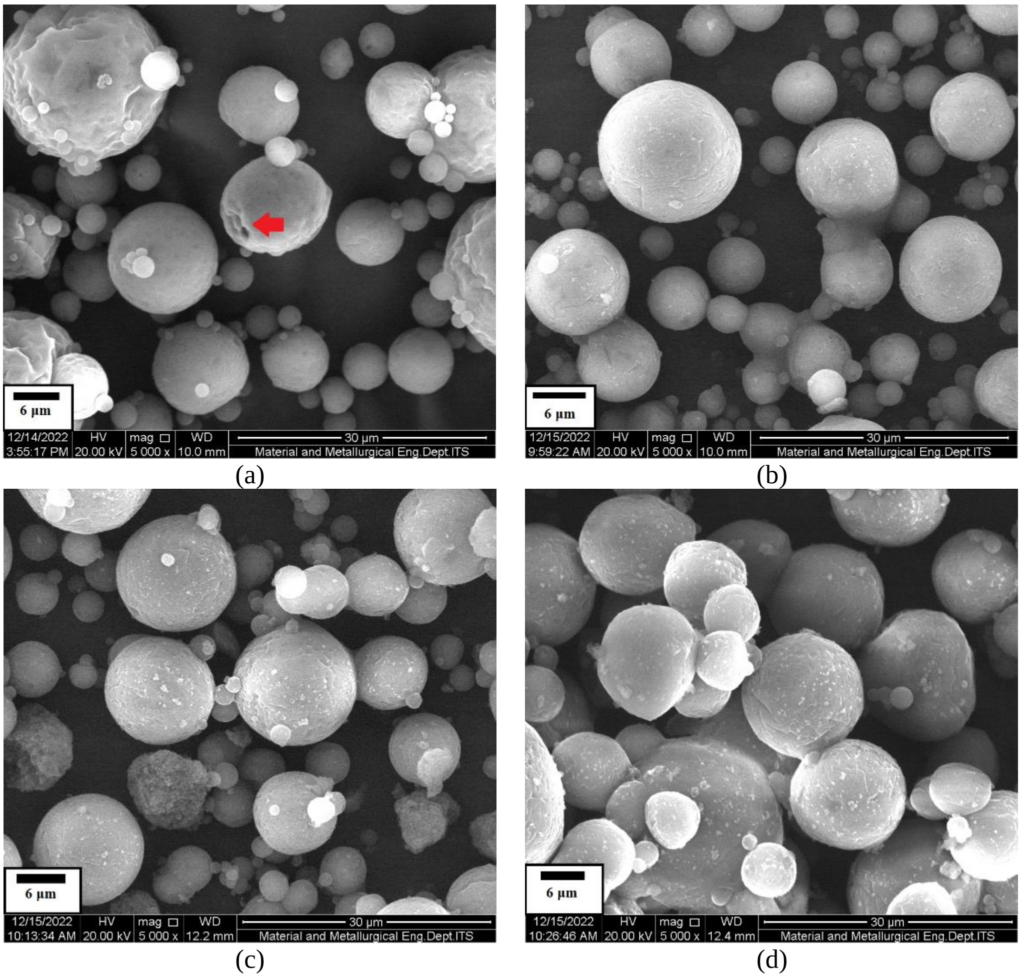
Gambar C.5 Pengaruh Suhu Inlet udara terhadap Wettability bubuk krimer

Pada **Gambar C.5** dapat dilihat lama waktu bubuk untuk terlarut dalam air dengan pada suhu 70 °C dengan adanya pengadukan 60 rpm**.** Waktu yang tercatat merupakan waktu saat larutan homogen. *Moisture content* pada analisa *wettability* berpengaruh dimana semakin besar *moisutrecontent* maka semakin cepat waktu untuk terlarutnya bubuk krimer. Menurut Goula dan Adamopoulos [6] bubuk dengan *moisture content* yang besar dan partikel yang kecil lebih cepat melarut dalam air. Pada perlakuan suhu *inlet* udara 180 °C (T50180) masih terdapat bubuk yang jumlahnya sangat sedikit yang terambang diatas air panas tersebut dimana didapatkan waktu yang lama untuk terlarutnya bubuk krimer tersebut walaupun mempunyai *moisture* yang lebih rendah.

C.1.6 Pengaruh Suhu Inlet udara terhadap morfologi SEM bubuk krimer

Analisa morfologi bubuk krimer, dilakukan dengan analisa SEM. Pada **Gambar C.6** merupakan hasil dari analisa SEM perbesaran 5000x (30µm). Apa bila ditinjau dari hasil morfologi, dapat dilihat secara kualitatif bahwa hasil pada TS50150 merupakan hasil morfologi yang terbaik bila dibanding dengan hasil pada perlakukan lainnya, dimana terlihat pada TS50150 tampak bundar (spherical). Hal ini sesuai dengan teori Mahdi et.al [7] dimana bentuk morfologi dengan bentuk yang *irregular* dapat menyebabkan kemampuan rehidrasi bubuk untuk meningkat. Bentuk morfologi yang baik menunjukan bahwa hasil salah satu faktor bubuk yang lebih tidak lengket. Semakin meningkatnya suhu *inlet* udara maka penggumpalan juga sedikit terjadi, tetapi pada suhu 180°C (TS50180). Pori – pori pecah karena setelah mencapai suhu terbaik, pori-pori pada surface mengalami pembesaran dan terjadi pemecahan [1].

Secara singkat hubungan antara suhu inlet udara yang meningkat terhadap moisture content menunjukan bahwa berkecenderungan turun . Hal ini berakibat terhadap kenaikan yield dan penurunan waktu *wettability*, akan tetapi pada suhu inlet udara 180°C mengalami peningkatan moisture content yang berakibat pada penurunan *yield* dan peningkatan waktu *wettability*. Selanjutnya trend peningkatan ukuran partikel rerata semakin meningkat dengan bertambah suhu inlet udara sebaliknya bulk density mengalami penurunan.



Gambar C.6 Pengaruh Suhu Inlet udara terhadap SEM bubuk krimer; (a) Suhu inlet udara 180 °C, (b) Suhu inlet udara 150 °C, (c) Suhu inlet udara 130 °C,(d) Suhu inlet udara 110 °C

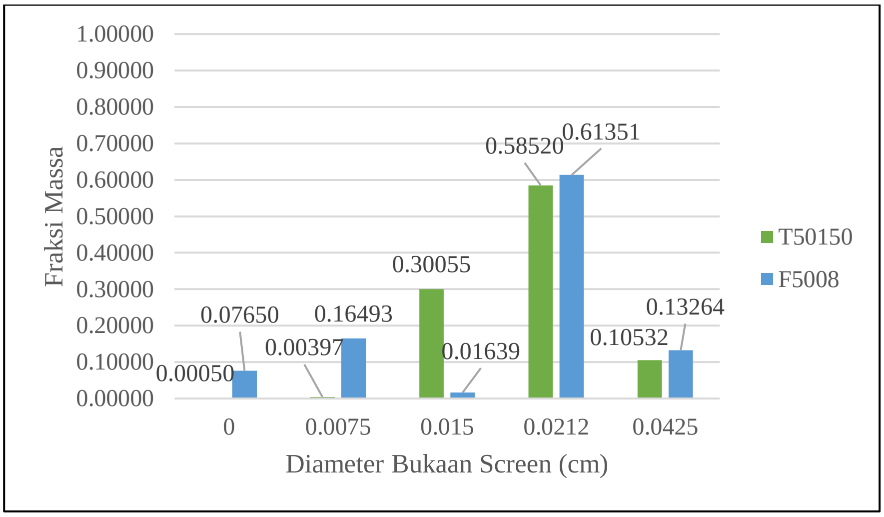
C.2 Pengaruh Laju Alir Umpan Emulsi O/W terhadap Karakteristik Bubuk Krimer

Pada tahap selanjutnya, pengaruh laju alir umpan pada proses pengeringan semprot terhadap karakteristik bubuk dipelajari melalui variasi 5 ml/min (TS50150) dan 8 ml/min (F5008). Parameter proses lainnya ditetapkan, antara lain tekanan udara pada nozzle 55 mm (1 bar), suhu inlet udara 150 °C, dan laju aspirator 100%).

Tabel C.3 Pengaruh laju alir umpan Emulsi O/W terhadap Karakteristik bubuk krimer

KODE	Laju Umpan (ml/min)	*Yield* overall %	Moisture content %	Bulk Density (g/ml)	Tapped Density (g/ml)	*Wettability* (Menit)	Ukuran Partikel Rata-rata (µm)
T50150	5	88,10%	2,9%	0,435	0,556	5.016	281,84
F5008	8	86,01%	3,5%	0,417	0,527	4.916	295,29

Berdasarkan **Tabel C.3** tampak bahwa yield bubuk mengalami penurunan dan kadar air mengalami peningkatan seiring dengan peningkatan laju alir umpan. Hal ini disebabkan oleh kurangnya waktu pengeringan bubuk saat keluar dari nozzle hingga mencapai dasar kolom karena waktu tinggal bubuk yang lebih singkat di sepanjang kolom. Laju alir umpan harus diatur sedemikian rupa untuk memastikan bahwa setiap droplet telah mencapai tingkat pengeringan tertentu sebelum mengenai dasar kolom. Peningkatan kadar air turut meningkatkan stickiness antar partikel yang ditunjukkan oleh peningkatan ukuran partikel, serta turut menurunkan yield. Pembentukan lapisan luar akan terhambat pada partikel berukuran besar sehingga memungkinkan keluarnya minyak ke permukaan partikel yang akan turut menurunkan yield [8].



Gambar C.7 Pengaruh laju alir umpan Emulsi O/W terhadap distribusi ukuran partikel

Dapat dilihat pada **Gambar C.7**, bahwa laju alir umpan tidak berpengaruh secara signifikan terhadap distribusi ukuran partikel.

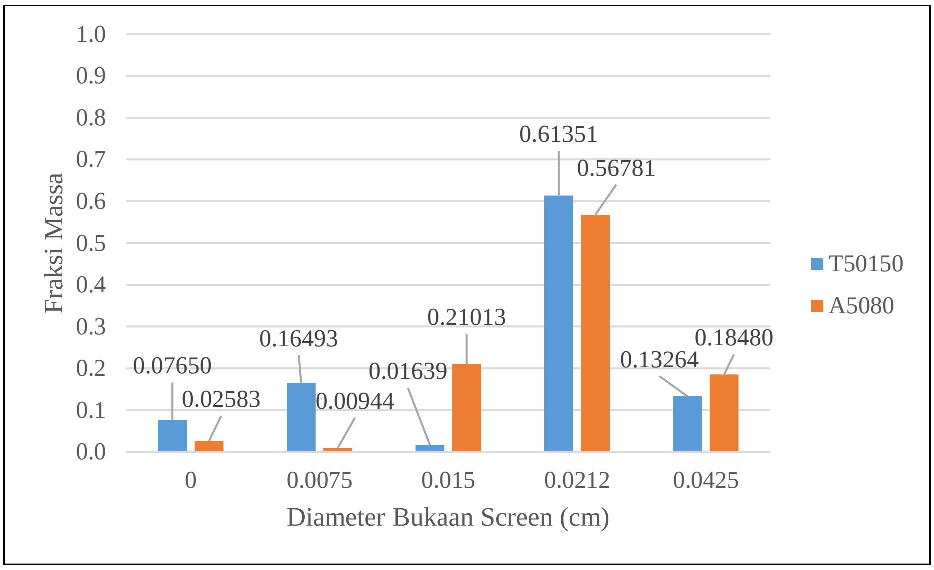
C.3 Pengaruh Laju Alir Udara Pengering (Laju Aspirator) terhadap Karakteristik Bubuk Krimer

Pada tahap selanjutnya, laju alir udara pengering/ laju aspirator divariasikan masing-masing pada 100% (TS50150) dan 80% (A5080), sedangkan parameter lainnya ditetapkan (laju alir umpan 5 ml/min, suhu inlet udara 150 ^{o}C, dan tekanan 1 bar). Karakteristik dari bubuk krimer yang dihasilkan dapat dilihat pada **Tabel C.4**.

Tabel C.4 Pengaruh Laju Alir Udara Pengering (Laju Aspirator) terhadap karakteristik bubuk krimer

KODE	Aspirator %	*Yield* overall %	Moisture content %	Bulk Density (g/ml)	Tapped Density (g/ml)	*Wettability* (Menit)	Ukuran Partikel Rata-rata (µm)
T50150	100	88,10%	2,9%	0,435	0,556	5.016	281,84
A5080	80	87,50%	3,2%	0,432	0,546	4.950	315,72

Berdasarkan **Tabel C.4,** tampak adanya kecenderungan yang mirip dengan kenaikan laju alir umpan apabila laju aspirasi diturunkan dari 100% menjadi 80% (sampel T150 vs. A80). Pada prinsipnya, waktu pengeringan partikel di dalam kolom akan meningkat apabila laju aspirasi atau laju udara pengering berkurang. Laju aspirasi yang tinggi akan meningkatkan laju evaporasi dan perpindahan massa uap air dari permukaan droplet ke udara pengering, di samping laju aspirasi yang tinggi dapat meningkatkan efisiensi pemisahan partikel-partikel kecil di siklon. Penurunan laju aspirasi mengakibatkan penurunan yield bubuk akibat peningkatan kadar air yang turut meningkatkan perlengketan antar partikel.



Gambar C.8 Pengaruh Laju Alir Udara Pengering (Laju Aspirator) terhadap distribusi ukuran partikel

Dapat dilihat pada **Gambar C.8**, bahwa laju alir udara pengering (laju aspirasi) tidak berpengaruh secara signifikan terhadap distribusi ukuran partikel.

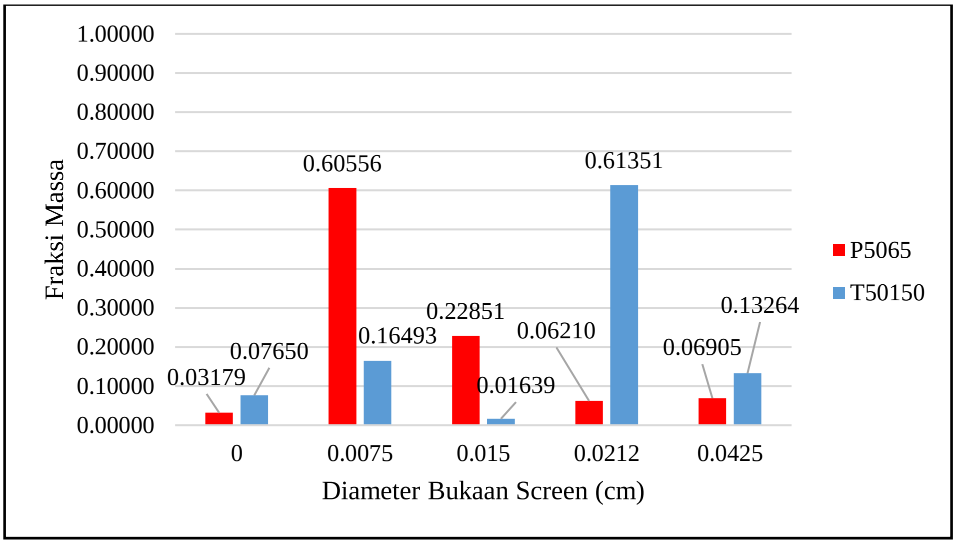
C.4 Pengaruh Tekanan Udara Nozzle terhadap Karakteristik Bubuk

Pada tahap selanjutnya, tekanan udara pada nozzle dipelajari pengaruhnya terhadap karakteristik bubuk yang dihasilkan selama proses pengeringan semprot. Tekanan divariasikan pada masing-masing 1 bar (TS50150) dan 1,8 bar (P5065), sedangkan parameter lainnya ditetapkan (alir umpan 5 ml/min, suhu inlet udara 150 ^{o}C, dan aspirator 100%). Karakteristik bubuk krimer yang dihasilkan dapat dilihat pada Tabel C.5.

Tabel C. 5 Pengaruh Tekanan Udara pada Nozzle terhadap Karakteristik bubuk krimer

KODE	**Tekanan**	***Yield* overall %**	**Moisture content %**	**Bulk Density (g/ml)**	**Tapped Density (g/ml)**	***Wettability* (Menit)**	**Ukuran Partikel Rata-rata (µm)**
T50150	55 mm (I bar)	88,10%	2,9%	0,435	0,556	5.016	281,84
P5065	65 mm (1,8 bar)	85,65%	3,3%	0,453	0,579	4.800	201,33

Berdasarkan **Tabel C.5,** tampak bahwa peningkatan tekanan udara pada nozzle mengakibatkan penurunan ukuran partikel. Hal ini disebabkan oleh adanya peningkatan energi pada droplet untuk mengatasi tegangan permukaan dan gaya viskos [9]. Di samping itu, tekanan udara pada nozzle dapat membantu proses atomisasi dan mengurangi kemungkinan buntu pada nozzle [9]. Namun demikian, yield bubuk berkurang dan kandungan air bubuk meningkat seiring dengan peningkatan tekanan udara pada nozzle. Tekanan udara kemungkinan besar terlalu besar sehingga dihasilkan bubuk yang sangat kecil. Bubuk yang sangat kecil ini memiliki luas permukaan yang besar untuk menyerap uap air dari lingkungan sehingga berpotensi terhadap proses perlengketan antar partikel. Pemilihan tekanan udara pada nozzle harus diatur sedemikian rupa sehingga tidak terlalu tinggi atau terlalu rendah [9].



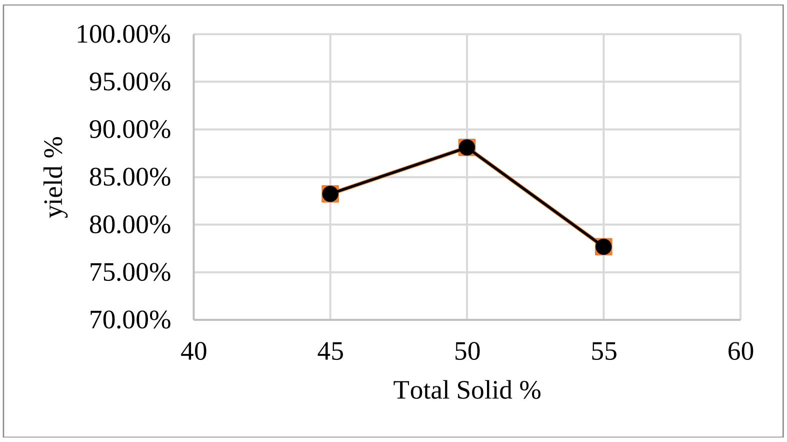
Gambar C.9 Pengaruh Tekanan Udara pada Nozzle terhadap distribusi ukuran partikel

Pada **Gambar C.9,** tampak bahwa tekanan udara pada nozzle yang meningkat menyebabkan penurunan ukuran partikel pada bubuk. Hal ini dapat dilihat dari pergeseran distribusi ukuran partikel ke sebelah kiri yang menunjukkan semakin mengecilnya ukuran bubuk dengan peningkatan tekanan udara pada nozzle.

C.5 Pengaruh *Total Solid* Emulsi O/W terhadap Karakteristik Bubuk

Pada tahap selanjutnya, total solid atau total padatan di dalam umpan emulsi O/W dipelajari pengaruhnya terhadap karakteristik bubuk krimer selama proses pengeringan semprot. *Total solid* yang divariasikan, antara lain 45% (TS45), 50 % (TS50150), dan 55 % (TS55). Parameter proses lainnya yang ditetapkan, antara lain laju alir umpan 5 ml/min, tekanan udara pada nozzle 55 mm (1 bar), suhu inlet udara 150 ºC, dan laju aspirator 100%. Setelah diperoleh bubuk krimer dari proses pengeringan semprot, yield bubuk krimer ditentukan dan karakteristik lainnya diujikan dan dikaji pada sub-bab di bawah ini.

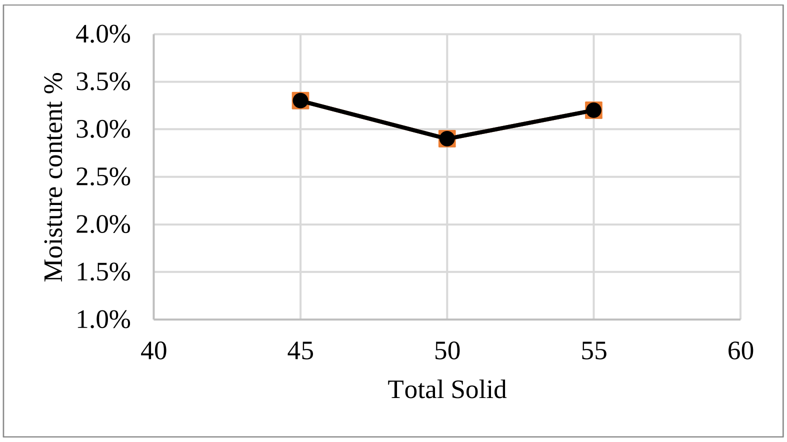
C.5.1 Pengaruh Total Solid Emulsi O/W terhadap Yield



Gambar C.10 Pengaruh *Total Solid* Emulsi O/W terhadap Yield

Pada **Gambar C.10,** tampak bahwa *yield* bubuk tertinggi dihasilkan pada total solid 50 % (T50150). Dari grafik tersebut, dapat disimpulkan di mana total solid dari bubuk dapat berpengaruh terhadap *yield* produk dimana ada total solid yang terbaik untuk mendapatkan *yield* yang terbaik. Sehingga dapat disimpulkan jika dikehendaki produk bubuk dengan tingkat perlengketan yang rendah, maka total solid yang terbaik perlu dicari untuk mendapatkan hasil yield yang terbaik.

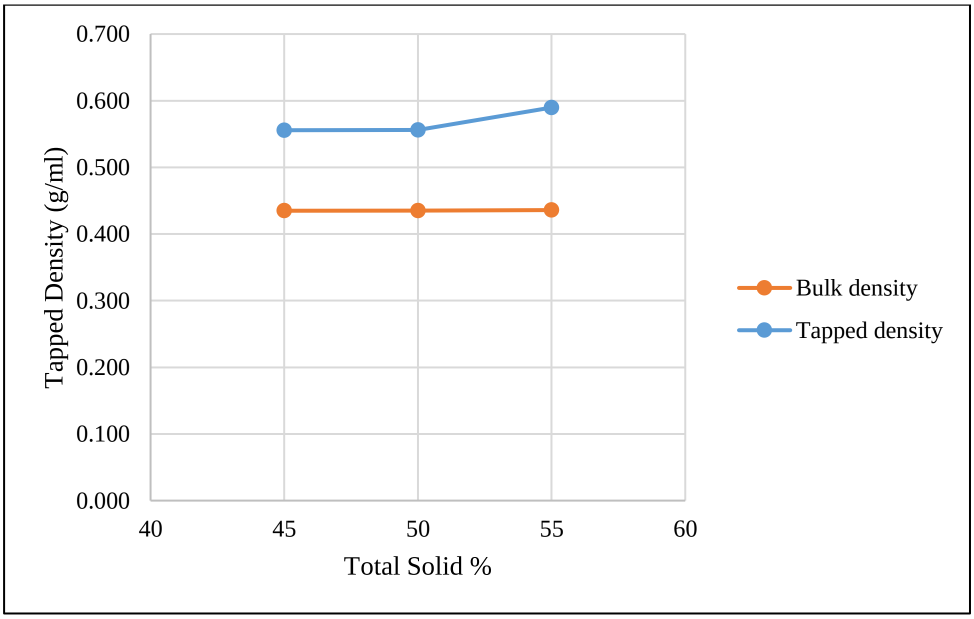
C.5.2 Pengaruh Total Solid Emulsi O/W terhadap Moisture Content



Gambar C.11 Pengaruh *Total Solid* Emulsi O/W terhadap Moisture Content

Pada **Gambar C.11**, tampak bahwa hasil bubuk dengan *moisture content* terendah diperoleh pada total solid 50 % (T50150). Kadar air yang rendah berimplikasi pada yield yang tinggi karena proses aglomerasi dan perlengketan antar partikel dapat diminimalkan. Laju penguapan dari permukaan droplet menurun seiring dengan penambahan viskositas umpan akibat peningkatan fraksi polimer di dalam campuran dengan meningkatnya total solid [10]. Pada konsentrasi total solid yang lebih rendah, partikel dengan ukuran yang lebih kecil akan lebih mudah terbentuk. Namun demikian, partikel yang jauh lebih kecil ini akan berkecenderungan untuk beraglomerasi karena lebih mudah menyerap air dari lingkungan yang berakibat pada penurunan yield.

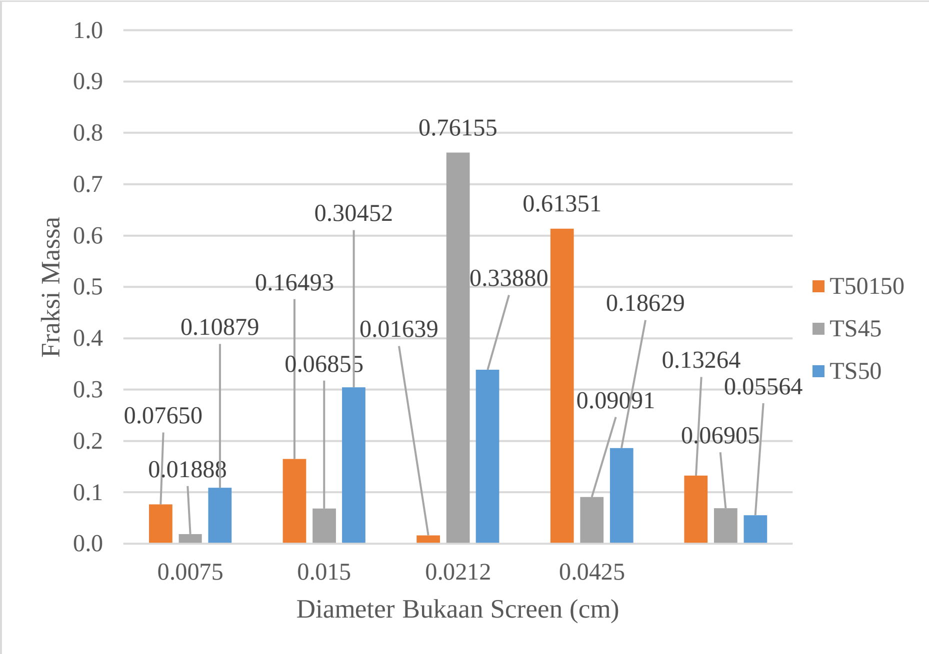
C.5.3 Pengaruh Total Solid Emulsi O/W terhadap Bulk Density dan Tapped Density



Gambar C.12 Pengaruh *Total* Solid Emulsi O/W terhadap Bulk Density dan *Tapped Density*

Pada **Gambar C.12** dapat dilihat pengaruh total solid terhadap *bulk* dan *tapped density* bubuk krimer. Dapat dlihat rata-rata untuk *bulk density* didapatkan sekitar 0,43 g/ml dan untuk *tapped density* didapatkan sekitar 0,56 g/ml. Menurut penelitian yang dilakukan oleh Quispe et.al. [11] densitas partikel meningkat saat *total solid %* meningkat. Hasil penelitian ini sejalan dengan hasil tersebut di mana peningkatan konsentrasi padatan di dalam umpan akan turut meningkatkan kekompakan dari bubuk yang dihasilkan.

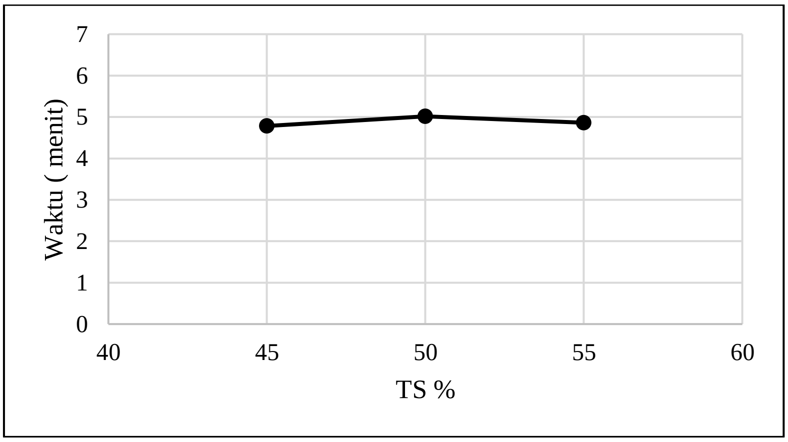
C.5.4 Pengaruh Total Solid Emulsi O/W terhadap Size Distribution Bubuk Krimer



Gambar C.13 Pengaruh *Total Solid* Emulsi O/W *terhadap Size Distribution* bubuk krimer

Pada **Gambar C.13** dapat dilihat bahwa pada *total solid* 50 % (T50150) memiliki distribusi ukuran partikel yang lebih besar dibandingkan dengan TS 45 dan TS 55. Lebih kecilnya ukuran partikel pada TS 55 kemungkinan besar dipengaruhi oleh vibrasi saat proses pengayakan yang menyebabkan benturan antar partikel sehingga terjadi pengecilan ukuran partikel. Ukuran partikel yang semakin kecil berkontribusi pada peningkatan kelengketan bubuk yang dihasilkan. Untuk total solid 50 % tampak bahwa kelengketan bubuk cukup minimal yang ditandai dengan tingginya yield bubuk yang dihasilkan.

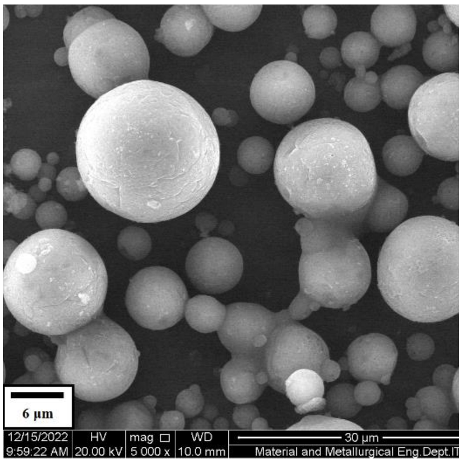
C.5.5 Pengaruh Total Solid Emulsi O/W terhadap Wettability



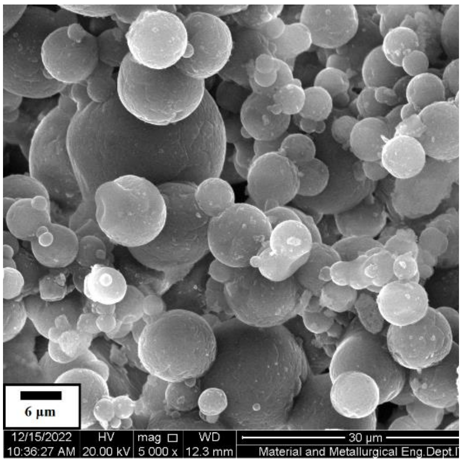
Gambar C.14 Pengaruh *Total Solid* terhadap Wettability

Analisa *wettability* pada **Gambar C.14** menunjukkan bahwa waktu yang diperlukan oleh bubuk krimer pada TS 50 untuk terbasahi hingga melarut sedikit lebih tinggi dibandingkan dengan bubuk yang dipersiapkan pada TS 45 dan 55. Hal ini turut dipengaruhi oleh ukuran dari partikel dan *moisture content* dari bubuk krimer.

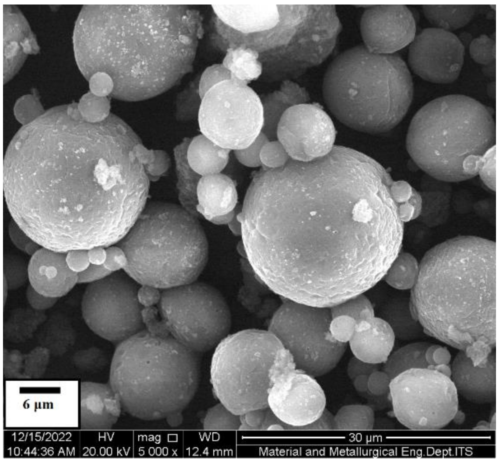
C.5.6 Pengaruh Total Solid Emulsi O/W terhadap Morfologi Bubuk Krimer



(a)



(b)



(c)

Gambar C.15 Pengaruh *Total Solid* Emulsi O/W terhadap SEM ; (a) Total solid 50%, (b) Total solid 45%, (c) Total solid 55%

Gambar C.15 merupakan hasil dari analisa SEM bubuk krimer dengan perbesaran 5000x. Secara kualitatif dapat dilihat pada TS45 dan TS55 terdapat lebih banyak partikel-partikel yang kecil yang beraglomerasi sehingga terjadi kelengketan, Hal ini dapat menyebabkan jumlah yield menurun. Sehingga dapat disimpulkan bahwa total solid paling optimum berada pada TS 50 (TS50150) di mana aglomerasi partikel tidak tampak secara signifikan. Hal ini sesuai dengan hasil uji moisture content di mana TS45 dan TS55 memiliki kadar moisture content yang lebih tinggi dibandingkan dengan TS50150.

C.6 Pengaruh *Filler* Emulsi O/W terhadap Karakteristik Bubuk

Pada tahap selanjutnya, jenis filler berupa Inulin (TS50150) dan IMO (IMO50) divariasikan untuk mempelajari pengaruhnya terhadap karakteristik bubuk, sedangkan parameter lainnya ditetapkan (laju alir umpan 5 ml/min , tekanan udara pada nozzle 55 mm (1 bar), suhu inlet udara pengering 150 ºC, dan laju aspirator 100%). Hasil karakterisasi bubuk krimer yang dihasilkan dikaji pada sub-bab di bawah ini.

C.6.1 Pengaruh Filler Emulsi O/W terhadap Yield, Moisture Content, Density, dan Wettability

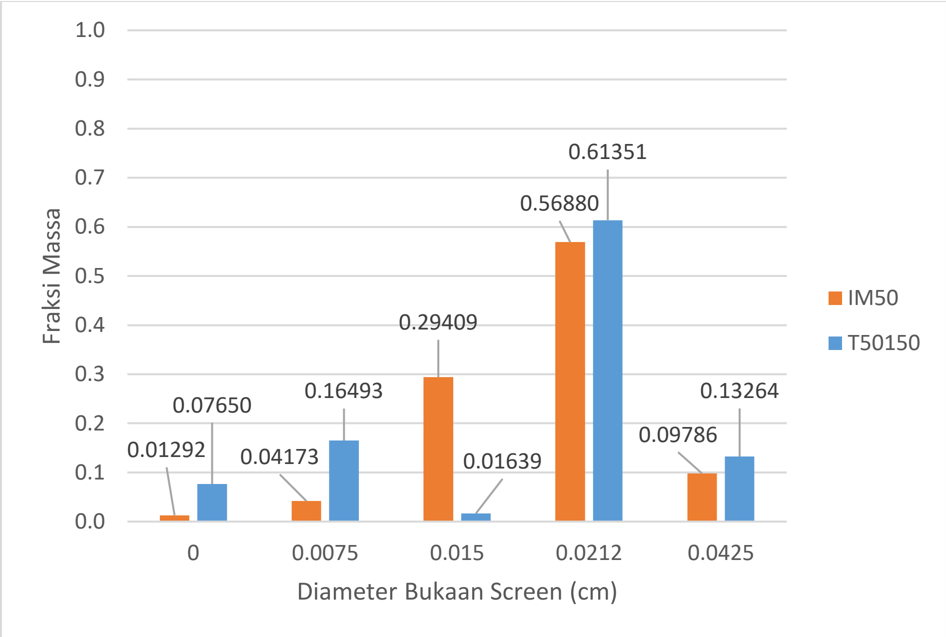
Tabel C.6 Pengaruh Filler terhadap Yield

KODE	Jenis Filler	*Yield* overall %	Moisture content %	Bulk Density (g/ml)	Tapped Density (g/ml)	*Wettability* (Menit)	Ukuran Partikel Rata-rata (µm)
T50150	Inulin	88,10%	2,9%	0,435	0,556	5.016	281,84
IMO50	IMO	65,67%	3,0%	0,456	0,627	7.350	289,78

Dari **Tabel C.6** dapat dilihat bahwa hasil bubuk dengan *yield* yang tertinggi adalah pada jenis filler inulin (T50150). Tampak bahwa jenis filler dapat berpengaruh terhadap *yield* produk di mana ada jenis filler yang terbaik untuk mendapatkan *yield* yang terbaik. *Moisture content* yang diperoleh tidak jauh berbeda dimana untuk jenis filler inulin didapatkan sebesar 2,9 % dan untuk jenis filler IMO (IMO50) sebesar 3,0%.

Bulk density dan tapped density tidak terlalu memiliki perbedaan yang cukup signifikan, tetapi pada uji wettability tampak bahwa sampel TS50150 lebih cepat larut pada air dibandingkan sampel IMO50. Hal ini dapat disebabkan oleh sifat IMO yang mempunyai *water holding capacity* yang tinggi.

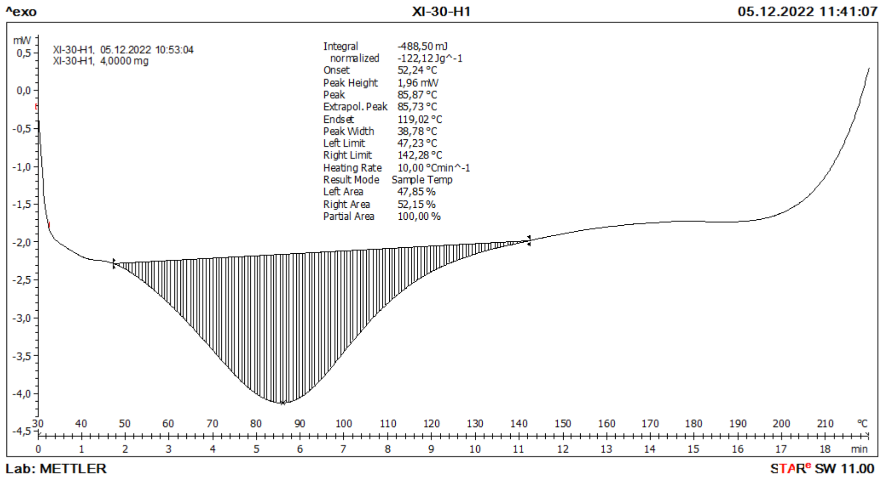
C.6.2 Pengaruh Filler Emulsi O/W terhadap Size Distribution



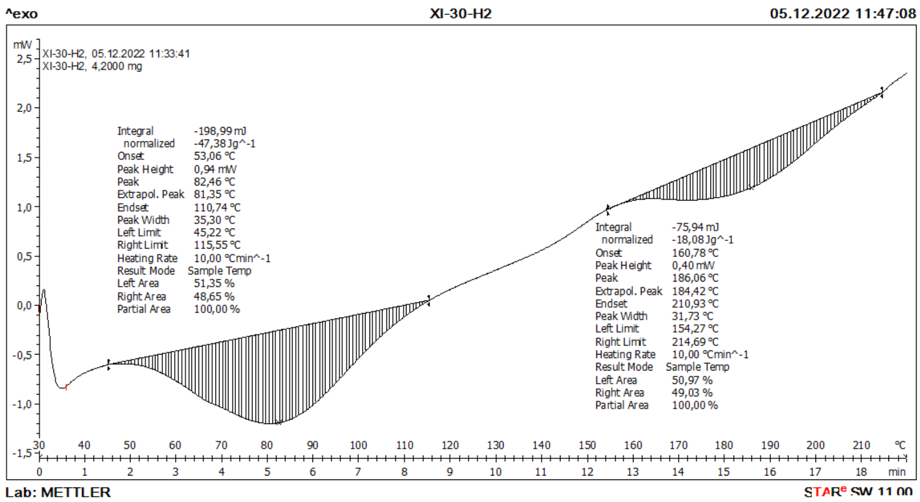
Gambar C.16 Pengaruh *Filler* Emulsi O/W terhadap *Size Distribution*

Pada **Gambar C.16** dapat dilihat bahwa bubuk dengan *filler* IMO memiliki lebih banyak fraksi dengan ukuran partikel yang lebih kecil. Semakin kecil ukuran partikel maka semakin lengket bubuk yang dihasilkan. Oleh karena itu bubuk dengan filler inulin (T50150) menghasilkan yield yang lebih besar dibandingkan dengan bubuk yang menggunakan filler IMO (IMO50).

C.6.3 Pengaruh Filler Emulsi O/W terhadap hasil Differential Scanning Calorimetry (DSC)



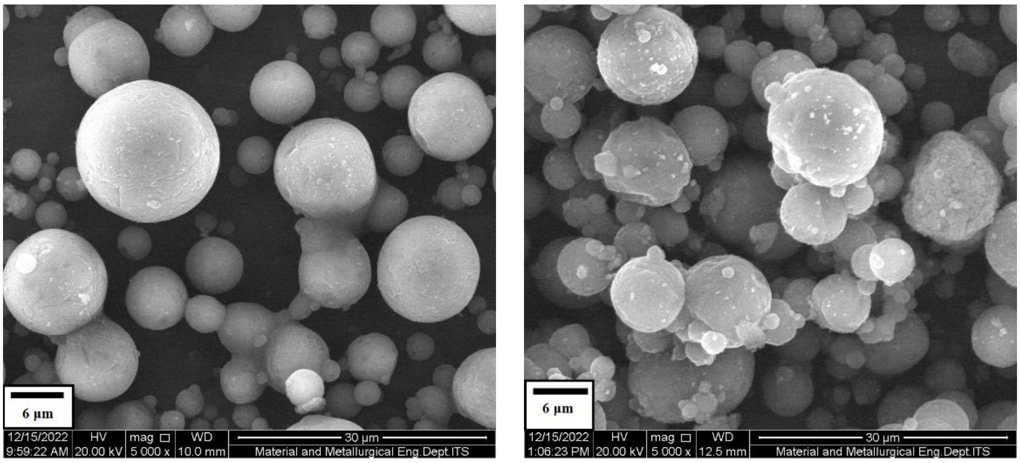
Gambar C.17 Hasil *Differential Scanning Calorimetry* (DSC) bubuk krimer dengan *filler inulin*



Gambar C.18 Hasil *Differential Scanning Calorimetry* (DSC) bubuk krimer dengan *filler IMO*

Pada **Gambar C.17** dan **Gambar C.18** dapat dilihat titik transisi gelas (T_g) yang ditunjukkan pada ujung lengkungan ke bawah (endotermis) dari bubuk, di mana pada bubuk dengan filler Inulin (T50150) diperoleh T_g sekitar 47,23 ºC sedangkan untuk filler IMO (IMO50) diperoleh Tg sekitar 45,22 ºC. Bubuk bersalut inulin dengan T_g yang lebih tinggi lebih tidak lengket daripada bubuk dengan filler IMO (Isomalto-oligosakarida) sehingga diperoleh yield yang lebih tinggi.

C.6.4 Pengaruh Filler Emulsi O/W terhadap hasil morfologi bubuk



(a) (b)

Gambar C.19 *Pengaruh Filler* Emulsi O/W terhadap morfologi SEM bubuk: (a) *filler* inulin , (b) *filler* IMO

Gambar C.19 merupakan hasil dari analisa SEM perbesaran 5000x (30µm). Pada filler IMO, terdapat partikel yang ber-aglomerasi. Aglomerasi tersebut dapat menyebabkan kelengketan. Hal ini dapat dibuktikan dengan perbedaan jumlah yield yang cukup signifikan yaitu, pada 88,10% (TS50150) dan 65,67% (IMO50)

C.6.5 Pengaruh Parameter Operasi terhadap Sifat Higroskopisitas Sampel

Tabel C.7 Pengaruh Parameter Operasi terhadap *Karakterisasi* Higroskopisitas

Kode Sampel	***Moisture Content %***						
	Moisture Awal	**10 menit**	**20 menit**	**30 menit**	**40 menit**	**50 menit**	**60 menit**
T50180	3,00%	3,39%	4,02%	4,79% *	5,33%	6,02%	6,43%
T50150	2,90%	3,50%	4,26%	4,72% *	5,33%	5,84%	6,31%
T50130	3,30%	3,76%	4,52%	4,97% *	5,40%	5,85%	6,38%
T50110	3,90%	4,24%	4,86% *	5,19%	5,71%	6,15%	6,59%
A5080	3,20%	3,77%	4,36%	4,88% *	5,28%	5,83%	6,45%
P5065	3,30%	3,70%	4,16%	4,68% *	5,33%	5,91%	6,38%
F5008	3,50%	3,89%	4,47%	4,92% *	5,38%	5,95%	6,46%
TS45	3,30%	3,66%	4,49%	4,96% *	5,36%	5,87%	6,29%
TS55	3,20%	3,59%	4,22%	4,80% *	5,27%	5,77%	6,31%
IMO50	3,00%	3,55%	4,12% *	4,71%	5,27%	5,71%	6,29%

* Titik kritis kadar air dimana bubuk krimer mulai menggumpal

Moisture content yang meningkat dapat menyebabkan formasi jembatan *liquid* (*formation of liqud bridges*) dimana partikel dapat menempel. Bubuk yang higroskopis dapat ditunjukkan dengan peningkatan *moisture content* dengan berjalannya waktu karena adanya absorbsi uap air oleh bubuk. Pada penelitian tersebut, saat dilakukan pengujian labuza, terjadi kenaikan *moisture content* dan pada suatu titik *moisture content* tertentu, bubuk tidak jatuh dari cawan petri. Hal ini menunjukkan bahwa pada suatu titik kritis *moisture content* tertentu dari suatu bubuk dimana bubuk menjadi sangat lengket. Pada penelitian tersebut bubuk dengan *filler* inulin mempunyai titik kritis 4,72 % dan untuk *filler* IMO 4,12 %. Tampak bahwa bubuk dengan filler inulin menunjukkan tingkat stickiness yang lebih rendah daripada menggunakan filler IMO karena titik kritis *moisture content* inulin lebih tinggi bila dibandingkan IMO.

D. **STATUS LUARAN**: Tuliskan jenis, identitas dan status ketercapaiansetiap luaran wajib dan luaran tambahan (jika ada) yang dijanjikan. Jenis luaran dapat berupa publikasi, perolehan kekayaan intelektual, atau luaran lainnya yang telah dijanjikan pada proposal. Uraian status luaran harus didukung dengan bukti kemajuan ketercapaian luaran sesuai dengan luaran yang dijanjikan. Lengkapi isian jenis luaran yang dijanjikan serta mengunggah bukti dokumen ketercapaian luaran melalui BIMA.

Luaran utama berupa manuskript luaran penelitian telah di-*submit* pada jurnal internasional bereputasi terindeks Scopus Q1 (Applied Food Research/ AFRES) dengan status *minor revision*.

Luaran tambahan berupa prototype produk bubuk VCO bersalut inulin dengan TKT 3.

E**. PERAN MITRA:** Tuliskan realisasi kerjasama dan kontribusi Mitra baik *in-kind* maupun *in-cash*serta mengunggah bukti dokumen pendukung sesuai dengan kondisi yang sebenarnya. Bukti dokumen realisasi kerjasama dengan Mitra dapat diunggah melalui BIMA.

Catatan:
Bagian ini wajib diisi untuk penelitian terapan, untuk penelitian dasar (Fundamental, Pascasarjana, PKDN, Dosen Pemula) boleh mengisi bagian ini (tidak wajib) jika melibatkan mitra dalam pelaksanaan penelitiannya

……
……

F. **KENDALA PELAKSANAAN PENELITIAN**: Tuliskan kesulitan atau hambatan yang dihadapi selama melakukan penelitian dan mencapai luaran yang dijanjikan, termasuk penjelasan jika pelaksanaan penelitian dan luaran penelitian tidak sesuai dengan yang direncanakan atau dijanjikan.

Masih diperlukan waktu tambahan untuk percobaan ulangan. Di samping itu, diperlukan pengolahan data dan menyajikannya dalam bentuk grafik atau tabel yang cukup komprehensif untuk revisi di jurnal AFRES. Masih diperlukan penelaahan ulang manuskript untuk perbaikan dan revisi dalam waktu dekat.

G**. RENCANA TAHAPAN SELANJUTNYA:** Tuliskan dan uraikan rencana penelitian selanjutnya berdasarkan indikator luaran yang telah dicapai, rencana realisasi luaran wajib yang dijanjikan dan tambahan (jika ada) di tahun berikutnya serta *roadmap* penelitian keseluruhan. Pada bagian ini diperbolehkan untuk melengkapi penjelasan dari setiap tahapan dalam metoda yang akan direncanakan termasuk jadwal berkaitan dengan strategi untuk mencapai luaran seperti yang telah dijanjikan dalam proposal. Jika diperlukan, penjelasan dapat juga dilengkapi dengan gambar, tabel, diagram, serta pustaka yang relevan. Jika laporan kemajuan merupakan laporan pelaksanaan tahun terakhir, pada bagian ini dapat dituliskan rencana penyelesaian target yang belum tercapai.

Rencana penelitian selanjutnya:

1. Melanjutkan pengumpulan data
2. Melakukan pengujian-pengujian lanjutan
3. Interpretasi data dan validasi data
4. Penelusuran jurnal-jurnal terkini untuk pembahasan hasil penelitian
5. Persiapan penulisan artikel publikasi untuk hasil penelitian dengan *novelty* yang tervalidasi.

H. DAFTAR PUSTAKA: Penyusunan Daftar Pustaka berdasarkan sistem nomor sesuai dengan urutan pengutipan. Hanya pustaka yang disitasi pada laporan kemajuan yang dicantumkan dalam Daftar Pustaka.

1. Abdullah, Z. *et al*. (2020) 'The effect of drying temperature and sodium caseinate concentration on the functional and physical properties of spray-dried coconut milk', *Journal of Food Science and Technology*. doi: 10.1007/s13197-020-04820-9.

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Studi Pengaruh Kondisi Proses Pengeringan Semprot terhadap Karakteristik Bubuk VCO (Virgin Coconut Oil) Bersalut Inulin

PROGRAM STUDI TEKNIK KIMIA UBAYA

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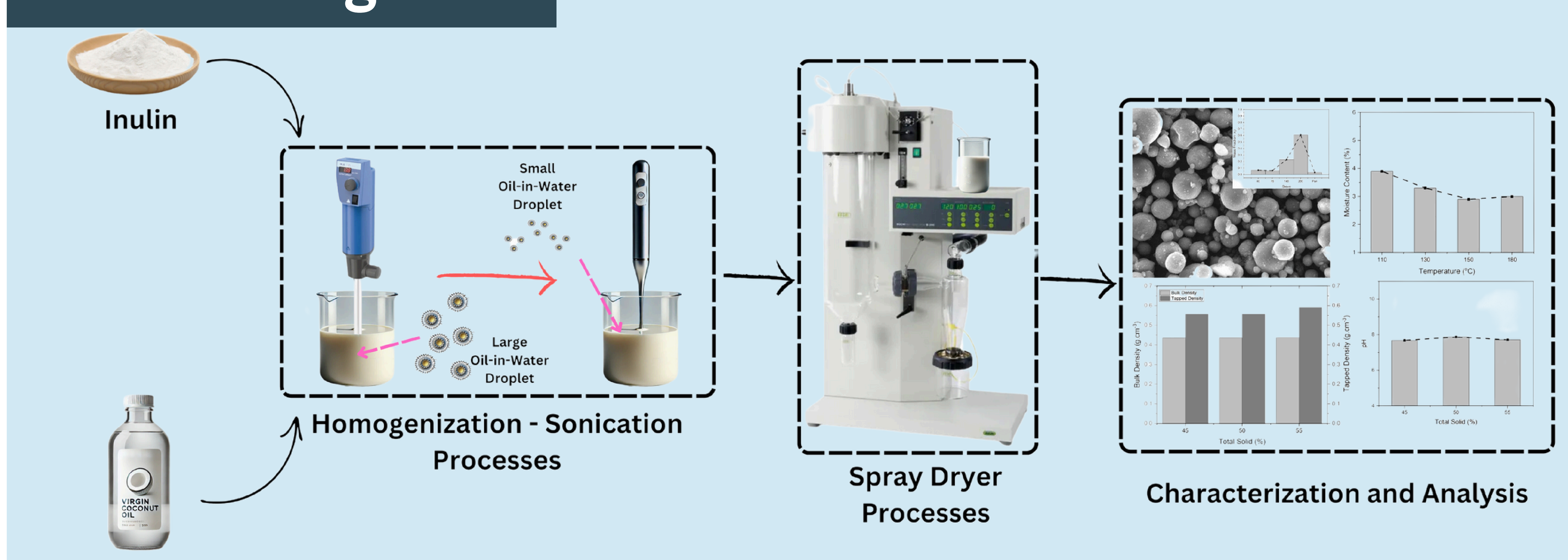
Abstrak

Minyak kelapa murni (VCO) dikenal memiliki manfaat kesehatan karena kandungan asam lemak rantai sedang dan antioksidannya yang tinggi. Namun, VCO rentan terhadap oksidasi, yang dapat menurunkan kualitas dan masa simpannya, sehingga membatasi aplikasi di industri pangan dan farmasi. Teknologi spray drying dengan inulin sebagai agen pelapis menawarkan solusi efektif untuk melindungi VCO dari oksidasi. Selain berfungsi sebagai pelapis, inulin juga memiliki manfaat kesehatan sebagai prebiotik, sehingga meningkatkan nilai fungsional produk. Penelitian ini bertujuan mengoptimalkan proses spray drying untuk menghasilkan bubuk VCO berlapis inulin dengan stabilitas, efisiensi enkapsulasi, dan karakteristik fisik yang diharapkan, serta membuka peluang aplikasi luas pada produk pangan dan farmasi.

(Kata Kunci : *Bubuk VCO, Emulsi O/W, Inulin, Temperatur Pengeringan, Pengeringan Semprot*)

Metodologi



Hasil Karakterisasi

Table 1. The Overall Experimental Variations

Sample	Inlet Air Temperature (°C)	Feed flow rate (ml/min)	Aspiration rate (%)	Air Pressure at Nozzle (bar)	Total Solid (%)
T180	180	5	100	1	50
T150	150	5	100	1	50
T130	130	5	100	1	50
T110	110	5	100	1	50
A80	150	5	80	1	50
P18	150	5	100	1.8	50
F08	150	8	100	1	50
TS45	150	5	100	1	45
TS55	150	5	100	1	55

Note: The sample code T was assigned for the variation in inlet air temperature; A for the variation in aspiration rate; P for the variation in air pressure at nozzle; F for the variation in feed rate; and TS for the variation in total solid

Table 2. Inulin-coated VCO powder characteristics

Sample	Yield (%)	Moisture content (%)	Bulk density (g/cm^3)	Tapped density (g/cm^3)	Average particle size (µm)	pH	Time of Rehydration (minute)
T180	86.38	3.0	0.3714	0.4776	474.45	7.662	6.500
T150	88.10	2.9	0.4351	0.5559	281.84	7.873	5.016
T130	83.76	3.3	0.4173	0.5272	165.88	7.797	4.900
T110	77.55	3.9	0.4668	0.5735	200.60	7.765	4.616
A80	87.50	3.2	0.4320	0.5457	315.72	7.839	4.950
P18	85.65	3.3	0.4438	0.5794	201.33	7.725	4.800
F08	86.01	3.5	0.4170	0.5267	295.29	7.726	4.916
TS45	83.23	3.3	0.4349	0.5557	210.64	7.683	4.783
TS55	77.67	3.2	0.4359	0.5897	187.54	7.713	4.866

Table 3. Flowability properties of inulin-coated VCO Powder

Sample	Carr's index (%)	Hausner ratio	Flowability
T180	22.24	1.29	passable
T150	21.73	1.28	passable
T130	20.85	1.26	passable
T110	18.61	1.23	fair
A80	20.84	1.26	passable
P18	23.40	1.31	passable
F08	20.83	1.26	passable
TS45	21.74	1.28	passable
TS55	26.08	1.35	poor

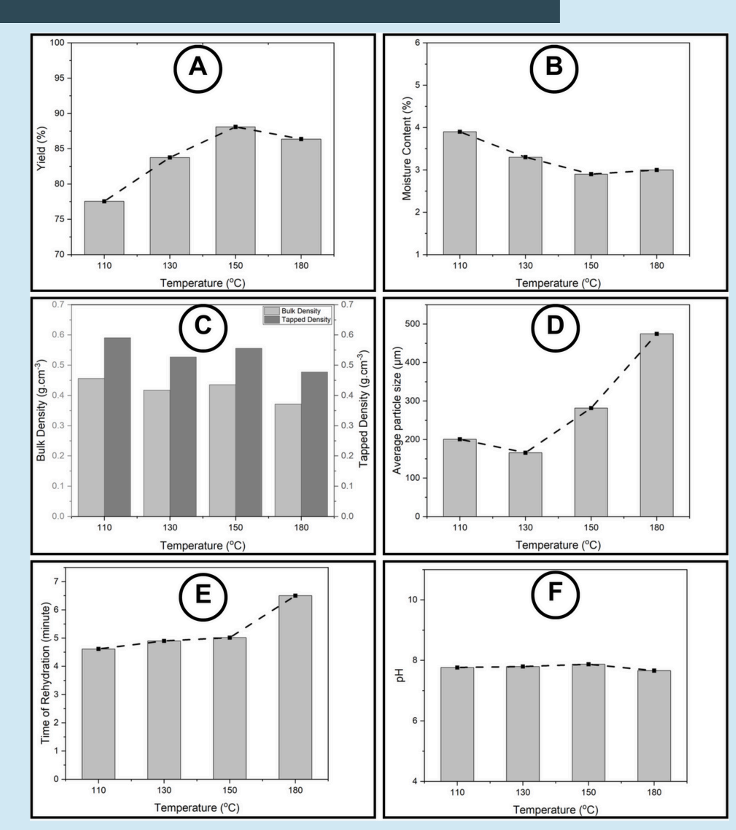
Kesimpulan

Parameter terbaik pada proses pengeringan semprot diperoleh pada suhu udara pengering 150°C; laju alir umpan emulsi O/W 5 ml/menit; laju aspirasi 100%; tekanan udara pada nozzle 1 bar. Di samping itu, konsentrasi padatan 50% sangat diperlukan untuk menghasilkan bubuk berkualitas tinggi dengan kadar air rendah, morfologi yang diharapkan, sifat alir yang baik, dan rendemen yang maksimal.

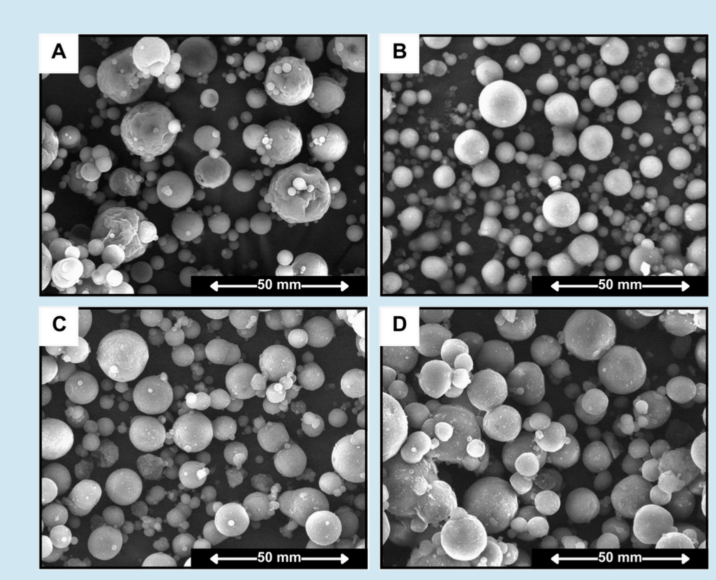
Hasil Luaran

Luaran Wajib	Luaran Tambahan
Paper submission to Applied Food Research Journal (Q1) entitled "Inulin-coated Virgin Coconut Oil (VCO) Powder Produced by Spray Drying" , Manuscript Number AFRES-D-24-00803	Prototype produk bubuk VCO bersalut inulin (TKT : 3)

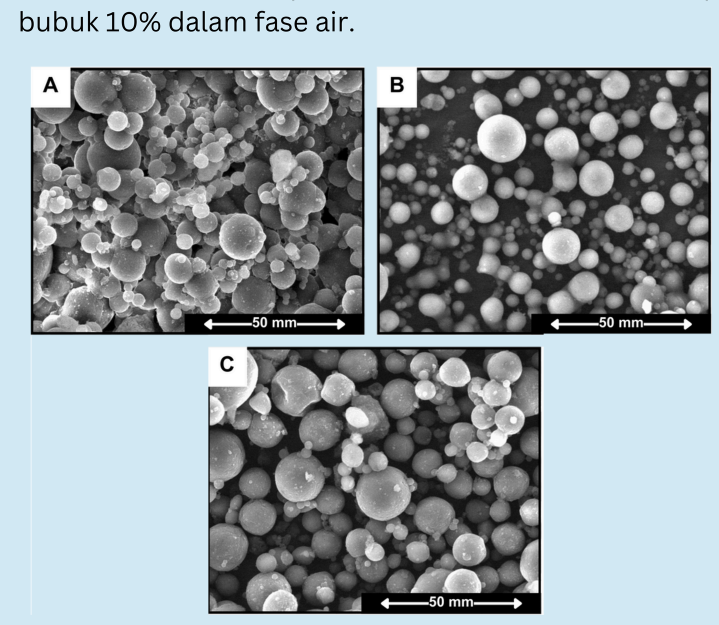
Hasil Analisis



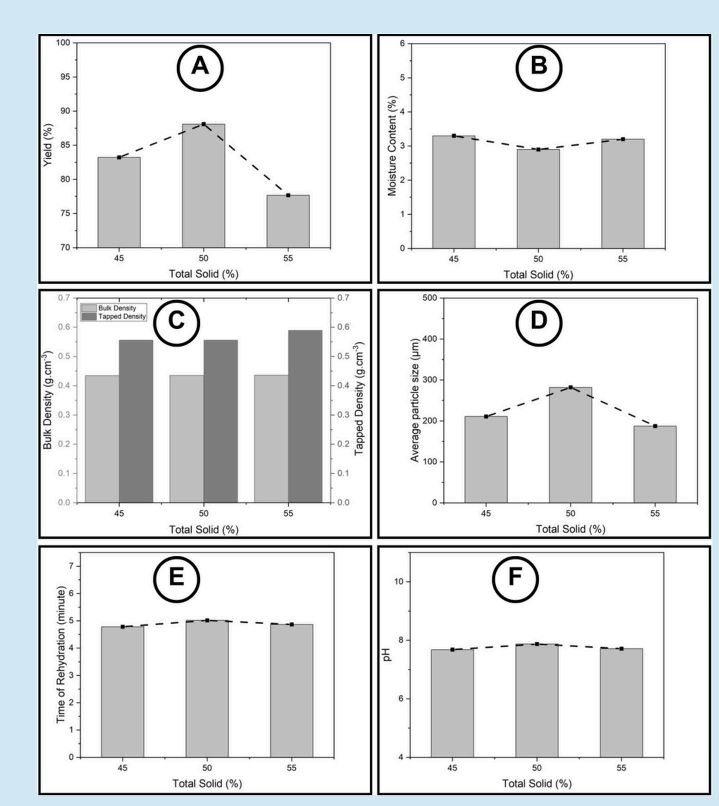
Gambar 1. Pengaruh suhu udara masuk terhadap karakteristik serbuk. (A) Yield; (B) Kadar air; (C) Densitas; (D) Rata-rata ukuran partikel; (E) Waktu rehidrasi; (F) pH bubuk 10% dalam fase air.



Gambar 2. Hasil SEM VCO berlapis inulin yang dikeringkan pada suhu udara pengeringan berbeda. (A) 180°C; (B) 150°C; (C) 130°C; (D) 110°C.



Gambar 4. Hasil SEM bubuk VCO berlapis inulin yang dibuat pada variasi total padatan dalam umpan emulsi. (A) 45%; (B) 50%; (C) 55%.



Gambar 3. Pengaruh total padatan terhadap karakteristik serbuk. (A) Yield; (B) Kadar air; (C) Densitas; (D) Rata-rata ukuran partikel; (E) Waktu rehidrasi; (F) pH bubuk 10% dalam fase air.

Daftar Pustaka

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Skema Hibah Penelitian Fundamental (Penelitian Kompetitif Nasional) berdasarkan Surat Keputusan Nomor 109/E5/PG.02.00.PL/2024 dan Perjanjian / Kontrak Nomor 004/SP2H/PT/LL7/2024, (054/SP-Lit/LPPM-01/KemendikbudRistek/FT/VI/2024).
Total Dana Penelitian : Rp 121.570.000,00

Applied Food Research

Inulin-coated Virgin Coconut Oil (VCO) Powder Produced by Spray Drying

--Manuscript Draft--

Manuscript Number:	
Full Title:	Inulin-coated Virgin Coconut Oil (VCO) Powder Produced by Spray Drying
Article Type:	Full Length Article
Keywords:	inulin; O/W emulsion; spray drying; VCO; yield
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Abstract:	The aim of this study is to produce inulin-coated virgin coconut oil (VCO) powder using spray drying technology. VCO, known for its high content of medium-chain fatty acids and antioxidants, has faced challenges in food and pharmaceutical applications due to its susceptibility to oxidation thus reducing its shelf-life. Inulin as the encapsulating agent, presented an effective solution, offering not only encapsulation efficiency but also added health benefits as prebiotics. The process parameters, such as inlet air temperature (110–180°C), feed flow rate (5–8 mL/min), aspiration rate (80-100%), and air pressure at nozzle (1–1.8 bar) as well as total solid percentage in the emulsion feed (45-55%) were varied. The best conditions were identified as inlet air temperature 150°C, feed flow rate 5 ml/min, aspiration rate 100%, air pressure at nozzle 1 bar, and 50% total solid content to produce powder with high yield (~88%), low moisture content (2.9%), and other desirable characteristics, such as density, particle size, morphology, and flowability. This novel inulin-coated VCO powder has the potential to offer broader applications in health-conscious consumer markets. Future studies should explore the scalability of this process for industrial production and assess the powder functionality in various food formulations.
Suggested Reviewers:	Azadeh Salimi Semanan University, Semann, Iran a.salimi@semnan.ac.ir He is conducting a lot of research using spray drying technology from O/W emulsion
	José, Toro-Sierra Chair for Food Process Engineering and Dairy Technology, Technical University of Munich Central Research Center for Nutrition and Food Sciences jose.toro@tum.de

	He is expert in spray drying processes and drying conditions
Additional Information:	
Question	**Response**
To complete your submission you must select a statement which best reflects the availability of your research data/code. IMPORTANT: this statement will be published alongside your article. If you have selected "Other", the explanation text will be published verbatim in your article (online and in the PDF). (If you have not shared data/code and wish to do so, you can still return to Attach Files. Sharing or referencing research data and code helps other researchers to evaluate your findings, and increases trust in your article. Find a list of supported data repositories in Author Resources, including the free-to-use multidisciplinary open Mendeley Data Repository.)	Data will be made available on request.
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To complete your submission you must select a statement which best reflects the availability of your research data/code. IMPORTANT: this statement will be published alongside your article. If you have selected "Other", the explanation text will be published verbatim in your article (online and in the PDF).	Data will be made available on request.

(If you have not shared data/code and wish to do so, you can still return to Attach Files. Sharing or referencing research data and code helps other researchers to evaluate your findings, and increases trust in your article. Find a list of supported data repositories in Author Resources, including the free-to-use multidisciplinary open Mendeley Data Repository.)	

Cover Letter

Dr.rer.nat. Lanny Sapei
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Surabaya 60293
East Java, INDONESIA

October 16, 2024

Dear Editor,

I wish to submit an original research article entitled “Inulin-coated Virgin Coconut Oil (VCO) Powder Produced by Spray Drying” for consideration by Applied Food Research Journal.

I confirm that this work is original and has not been published elsewhere, nor is it currently under consideration for publication elsewhere.

In this paper, I report on the novel production of VCO powder encapsulated with inulin using spray drying technology. VCO is considered to be healthy oil despite of their major saturated fatty acids. VCO also demonstrates an antimicrobial and antiviral activity. However, VCO in liquid form is prone to oxidation thus limiting its shelf-life. Inulin was selected as pure encapsulant polysaccharide materials due to its health benefit as prebiotics. This research investigated the influence of spray drying process (inlet air temperature, feed flow rate, aspiration rate, air pressure at nozzle), and feed concentration in order to obtain powder with high yield, low moisture content, and other desirable characteristics (bulk density, tapped density, particle size, morphology, and flowability). The properties of reconstituted VCO powder were studied in terms of pH and time of rehydration for further applications. This novel inulin-coated VCO powder has the potential to offer broader applications in health-conscious consumer markets.

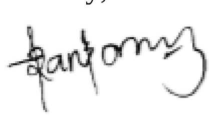
We believe that this manuscript is appropriate for publication by Applied Food Research Journal because it fits with the scope of the journal related to scientific and technological applications of food science and enginering. This manuscript reflects a cutting-edge research and design of technology that would be beneficial for both practitioners and academicians.

We have no conflicts of interest to disclose.

Please address all correspondence concerning this manuscript to me at lanny.sapei@staff.ubaya.ac.id.

Thank you for your consideration of this manuscript.

Sincerely,



Dr.rer.nat. Lanny Sapei

Declaration of competing interest

All authors disclose no conflicts of interests

Funding statement

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Data availability

The data generated in this research are available from the corresponding author on reasonable request.

Declaration of generative AI in scientific writing

During the preparation of this work the author(s) used ChatGPT in order to improve the language and writing. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

Ethical statement
All authors disclose no studies in humans and animals.

Title Page

Inulin-coated Virgin Coconut Oil (VCO) Powder Produced by Spray Drying

Lanny Sapei[1,*], Pra Cipta Buana Wahyu Mustika[1], Putu Doddy Sutrisna[1], Rudy Agustriyanto[1], Grace Vita Santoso[1], Justinus Putra Utama[1], Rochmad Indrawanto[2]

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Abstract

The aim of this study is to produce inulin-coated virgin coconut oil (VCO) powder using spray drying technology. VCO, known for its high content of medium-chain fatty acids and antioxidants, has faced challenges in food and pharmaceutical applications due to its susceptibility to oxidation thus reducing its shelf-life. Inulin as the encapsulating agent, presented an effective solution, offering not only encapsulation efficiency but also added health benefits as prebiotics. The process parameters, such as inlet air temperature (110–180°C), feed flow rate (5–8 mL/min), aspiration rate (80-100%), and air pressure at nozzle (1–1.8 bar) as well as total solid percentage in the emulsion feed (45-55%) were varied. The best conditions were identified as inlet air temperature 150°C, feed flow rate 5 ml/min, aspiration rate 100%, air pressure at nozzle 1 bar, and 50% total solid content to produce powder with high yield (~88%), low moisture content (2.9%), and other desirable characteristics, such as density, particle size, morphology, and flowability. This novel inulin-coated VCO powder has the potential to offer broader applications in health-conscious consumer markets. Future studies should explore the scalability of this process for industrial production and assess the powder functionality in various food formulations.

Keywords: inulin, O/W emulsion, spray drying, VCO, yield

1. Introduction

Virgin coconut oil (VCO) has gained increasing attention due to its numerous health-promoting properties and wide applicability in various industries such as food, nutraceuticals, cosmetics, and pharmaceuticals (Babu et al., 2014; Ng et al., 2021; Srivastava et al., 2016; Zeng et al., 2024). Extracted from the fresh meat of mature coconuts (*Cocos nucifera*), VCO is particularly rich in medium-chain fatty acids (MCFAs), especially lauric acid, which accounts for nearly 50% of its fatty acid content (Araújo de Vasconcelos et al., 2023). Lauric acid is renowned for its potent antimicrobial, antiviral, and antifungal properties (Araújo de Vasconcelos et al., 2023). Furthermore, VCO is rich in antioxidants, including tocopherols and polyphenols, which contribute to its protective effects against oxidative stress and inflammation (Mansouri et al., 2024).

Despite its many advantages, the liquid form of VCO presents certain challenges related to stability, storage, handling, and incorporation into food and pharmaceutical formulations (Jafari & Samborska, 2021). One major issue is its susceptibility to oxidation, which can lead to rancidity and loss of beneficial properties over time (Corrêa-Filho et al., 2022). In addition, the liquid nature of VCO limits its versatility in certain product applications where powdered ingredients are preferred due to their ease of transport, longer shelf life, and ability to mix more uniformly in dry formulations (Sánchez-Osorno et al., 2023).

Spray drying is one of the most widely used microencapsulation techniques for converting oils into powders (Jafari & Samborska, 2021; Quispe et al., 2020; Sánchez-Osorno et al., 2023). This process involves atomizing the liquid feed (such as VCO) into small droplets, which are then rapidly dried using hot air, resulting in fine powders (Sánchez-Osorno et al., 2023). The spray drying technique is favored for its scalability, cost-effectiveness, and ability to produce powders with good flow properties (Gharsallaoui et al., 2007; Jafari & Samborska, 2021; von Halling Laier et al., 2019). However, the success of the spray drying process largely depends on the choice of wall materials used for encapsulation (Quispe et al., 2020; Sánchez-Osorno et al., 2023).

In recent years, inulin, a natural polysaccharide, has emerged as a promising wall material for the microencapsulation of sensitive compounds like oils (Sánchez-Osorno et al., 2023). Inulin is a soluble dietary fiber extracted from plants, such as chicory root, agave, and Jerusalem artichoke (Mazloom et al., 2012). It is composed primarily of fructose units linked by β-(2→1) glycosidic bonds, and its degree of polymerization can vary from 2 to 60 fructose units (Mazloom et al., 2012). Inulin is recognized not only for its technological properties but also for its numerous health benefits (Corrêa-Filho et al., 2022; Mazloom et al., 2012).

In the context of microencapsulation, inulin offers several advantages as a wall material (Corrêa-Filho et al., 2022). It has excellent film-forming properties, which allow for the formation of a protective barrier around the encapsulated oil (Corrêa-Filho et al., 2022; Sánchez-Osorno et al., 2023). Moreover, inulin is resistant to digestive enzymes in the human gastrointestinal tract, which enables the controlled release of encapsulated bioactive compounds, such as VCO, in the lower intestine where it can exert its full functional effects (Corrêa-Filho et al., 2022; Mazloom et al., 2012). Inulin is belonged to soluble dietary fiber which helps stabilize blood sugar and reduce the diabetes risk (Giuntini et al., 2022; Niero et al., 2023; Wijaya et al., 2022). The recommended fiber intake per day is 25-40 gram/ day, however, the average fiber consumption of the local people is still below 21 gram/ day (Novianti et al., 2023).

Previous research has demonstrated the potential of spray drying to encapsulate oils, including VCO, using various wall materials (Jafari & Samborska, 2021; Mazloom et al., 2012). For instance, recent studies have explored the use of maltodextrin and other polysaccharides as wall materials for spray drying VCO (Jafari & Samborska, 2021). However, while maltodextrin is a commonly used wall material due to its low cost and good solubility, it lacks the additional health benefits provided by inulin (Corrêa-Filho et al., 2022; Mazloom et al., 2012). In contrast, recent investigations have shown that inulin contributes significantly to the encapsulation efficiency and enhances the antioxidant properties of the final product when used as a wall material for encapsulating oils (Corrêa-Filho et al., 2022; Sánchez-Osorno et al., 2023). Additionally, inulin also functions as stabilizing agent for the oil-in-water (O/W) emulsion due to its thickening power (Sapei et al., 2023), which contributes to the enhancement of the encapsulation efficiency during spray drying process. This highlights the potential of inulin as an alternative or supplementary wall material for encapsulating oils, especially for functional foods designed for health-conscious consumers.

The present study aims to explore the feasibility of producing inulin-coated VCO powder using spray drying as the microencapsulation technique. The study focuses on optimizing the spray drying parameters to achieve high encapsulation efficiency and desirable physical properties such as low moisture content, appropriate particle size, and good flowability (Jafari & Samborska, 2021; Sánchez-Osorno et al., 2023). Additionally, the research evaluates the pH and rehydration of the spray-dried VCO powder in aqueous systems to assess its potential for use in functional food formulations (Corrêa-Filho et al., 2022). This study seeks to contribute to the growing body of knowledge on microencapsulation technologies, particularly the use of inulin as a wall material for encapsulating functional oils like VCO and explore how drying parameters such as inlet air temperature, feed flow rate, aspiration rate, and air pressure at nozzle, as well as feed formulation influenced on the powder yield and characteristics. The encapsulation of VCO in powdered form not only extends its shelf life but also opens up new possibilities for its application in a broader range of food and health products. By leveraging the health benefits of both VCO and inulin, this research aims to develop a novel functional ingredient with improved stability and enhanced nutritional value.

2. Materials and Methods

2.1 Materials

Virgin coconut oil (VCO) comprising of 0.5% caproic acid, 4.5% caprylic acid, 5.85% capric acid, 45% lauric acid, 20% myristic acid, 11% palmitic acid, 3.5% stearic acid, 8% oleic acid, 1.6% linoleic acid, and 0.05% linolenic acid; sodium caseinate; glycerol monostearate (GMS) powder with total monoglycerides min. 95%; phosphates salts (K_2HPO_4); inulin (dry matter content 96.8%; pH 5.5; inulin 90%, fructose/glucose/sucrose 10%); anti-caking agent (SiO_2); demineralized water.

2.2 Preparation of Oil-in-Water (O/W) Emulsion

Demineralized water as the continuous phase was prepared according to the total solid content in the whole emulsion (45%, 50%, and 55%) and then heated to 70°C and poured into a 1 L stainless steel vessel. Afterwards, other ingredients were added in a consecutive manner according to each component percentage (% weight/ weight) dry basis of total solid content. All components except demineralized water were perceived as total solid. Inulin of about 61.5% was firstly added and the mixture was homogenized using a rotor-stator (IKA T25 digital ULTRA TURRAX, Germany) at 15,000 rpm for 5 minutes followed by the addition of phosphate salts of 2.5% and mixing at 15,000 rpm for 3 minutes. Sodium caseinate of 2.5% was added followed by mixing at 15,000 rpm for 5 minutes. Afterwards, GMS of 1% was added and the mixture was dispersed at 15,000 rpm for 3 minutes. Eventually, VCO at 60°C was added to the mixture of about 32% followed by homogenization at 15,000 rpm for 10 minutes. The water loss after rotor-stator homogenization was compensated by adding water into the mixture. Finally, the mixture was subjected to the probe sonicator (Sonicator Q-700, QSonica, USA) with a replaceable tip Ea ½ inch for 5 minutes using the amplitude of 100%.

2.3 Production of VCO Powder

The temperature of O/W emulsion was kept at 70°C using a waterbath (Joanlab WB100-1F, China) when being fed into the mini spray dryer (BÜCHI B-290, Büchi Labortechnik AG, Switzerland) by means of hot air as drying medium. Several drying parameters such as temperature of inlet air (110°C; 130°C; 150°C; 180°C), aspiration rate of inlet air (80%; 100%), air pressure at nozzle (1 bar; 1.8 bar), and flow rate of the emulsion feed (5 ml/min; 8 ml/min) were adjusted using O/W emulsion with the total solid of 50%. The obtained best drying parameters were then applied for other total solids of 45% and 55%. The overall experimental variations were depicted in Table 1. The emulsion entered the 0.7 mm two-fluid nozzle and atomized into droplets which in turn were in contact with the hot air. The hot air contacted with the droplet in a co-current manner. The air left at the temperature ranges of 75-100ºC. Water was evaporated from the droplets and inulin-coated VCO powders were collected at the bottom of drying chamber. The spray dried particles conveyed by the drying air was separated by the cyclone. The overall free-flowing VCO powders were collected, mixed with 0.5% anti-caking agent, and weighed for the yield determination. The powder was placed in an aluminum pouch and stored at the room temperature for further characterization.

2.4 Analysis of VCO Powder

The characteristics of produced inulin-coated VCO powder such as yield, moisture content, pH of 10% solution, untapped/ bulk density and tapped density, wettability, particle size distribution, flowability properties, and morphology were determined.

Powder Yield

The powder yield was calculated according to Equation (1), whereby %MC is moisture content of powder in percentage and % TS is total solid content of the O/W feed emulsion in percentage.

$$\text{Yield (\%)} = \frac{\text{Total mass powder}}{\text{(1+\%MC)x (total mass feed x \%TS)}} \text{x } 100\% \quad (1)$$

Moisture Content

The moisture content of 2 g VCO powder was measured using the moisture balance (MOC-120H, Shimadzu, Japan) operated at 105°C. The moisture content (% wet basis) was reported.

Bulk density and tapped density

Untapped or bulk density was calculated by dividing the weight of the powder with the volume occupied by the powder in g/cm^3. About 10 g of powder was placed into a 100 ml volumetric flask and the occupied volume of the powder was recorded. The tapped density was similarly measured while tapping the powder for about 100 times prior to volume recording.

pH of reconstituted powder

Reconstituted VCO powder was prepared by dissolving 10 g of VCO powder into 100 ml demineralized water at 70°C and stirred using a magnetic stirrer at 60 rpm. The pH of dissolved VCO powder at 10% (w/v) in aqueous solution was measured at room temperature using a pH-meter (inoLab® pH 7110, WTW, Germany).

Time of rehydration

The determination of rehydration time was based on modified procedures described by Salimi et al. (2018). It was determined by monitoring time required to hydrate and dissolve 10 g VCO powder in 100 ml water at 70°C while stirring using a magnetic stirrer at 60 rpm.

Powder fractionation

Powder of about 20 g were sieved using a test sieve shaker consisting of a set of sieves with different mesh sizes (40, 70, 100, and 200 mesh) (Retsch, Germany) at amplitude of 40 for 2 min. The powder retained in each sieve was weighed to determine the proportion of mass fraction in each sieve. Particle size distribution (*supplementary data*) and the average particle size ($\overline{D}$) was determined according to Equation (4)

$$D_n = \frac{D_p + D_{p-1}}{2} \tag{2}$$

$$x_i = \frac{\text{mass of retained powder at sieve i}}{\text{total mass of feed powder}} \tag{3}$$

$$\overline{D} = \sum x_i . D_{n,i} \tag{4}$$

where D_p is opening diameter of sieve with certain mesh size, x_i is mass fraction of the powder retained at the certain sieve.

Flowability properties

Flow behavior of the powder in term of flowability was determined using two empiric parameters, namely Carr's index (%CI) and Hausner ratio (HR) based on bulk density and tapped density according to Equation (5) and (6), respectively (Mahdi et al., 2020).

$$\%CI = \frac{\text{Tapped density} - \text{Bulk density}}{\text{Tapped density}} \text{x}100\% \tag{5}$$

$$HR = \frac{\text{Tapped density}}{\text{Bulk density}} \tag{6}$$

Morphology

The VCO powder morphology was studied using SEM (FEI Inspect S50, FEI, USA). A double-sided tape was attached to the aluminum stub on which a small amount of sample was placed. The specimens were sputtered with gold to improve the conductivity prior to analysis. The analysis was conducted at 20 kV and at the magnification of 2500x.

3. Results and Discussion

The production of inulin-coated VCO powder using spray drying process was highly affected by the spray drying process parameters, such as inlet air temperature, aspiration rate, air pressure at nozzle, and feed rate. Furthermore, the composition of O/W emulsion feed such as total solid percentage also played an important role in the drying process, thus influencing the characteristics of the obtained powder. The overall inulin-coated VCO powder characteristics as well as their flowability properties could be seen in Table 2 and Table 3, respectively.

3.1 Effect of inlet air temperature on inulin-coated VCO powder characteristics

The inlet drying air temperatures were varied from 110-180°C (samples T110, T130, T150, and T180) using 50% total solid of the O/W emulsion feed. Other drying process parameters such as feed rate (5 ml/min), aspiration rate (100%), and air pressure at nozzle (1 bar) were kept constant. It turned out that powder yield was linearly increased with the increase in inlet air temperature from 110°C to 150°C and slightly decreased at 180°C as shown in Figure 1A. Higher temperature provided higher rates of water removal thus reducing the stickiness among particles. However, drying at 180°C seemed to be too high and was likely to induce powder gelatinization thus increasing the cohesion between the particles or adhesion between the particle and chamber wall leading to reduced yield.

Furthermore, the moisture content showed an opposite pattern with the yield (Figure 1B). The moisture content of VCO powder was decreasing with the increasing inlet air temperature until 150°C and slightly increased at 180°C. It has been known that the inlet drying air temperature is the driving force of heat transfer from drying air to the droplet and water vapor mass transfer from the droplet into the air. Therefore, the higher the inlet air temperature, the faster the evaporation rate and the drying process, resulting in the reduction of powder moisture content (Abdullah et al., 2021; Gharsallaoui et al., 2007). However, the when the temperature of inlet air was too high, the diffusion of water from the inner droplet to the droplet surface could be impeded due to the onset of crust formation prior to complete water removal. This was called ballooning phenomena (Goula & Adamopoulos, 2012; Salimi et al., 2018), whereby water vapor entrapped inside the powder could explode (Abdullah et al., 2021) leading to particle irregularities. The suppression of powder moisture content has been beneficial in preventing powder agglomeration (Hedayatnia et al., 2016). The moisture contents of the overall VCO powder were low enough, i.e., below 5% (Abdullah et al., 2021; Hedayatnia et al., 2016) and fulfill the general requirement as food ingredients. However, the higher the moisture content the higher the tendency of the particles to be sticky one another causing powder caking. This could possibly occur based on the fact that the transition glass temperature (Tg) of powder tended to be lowered with the increased of moisture content (Hedayatnia et al., 2016) which would affect the powder shelf-life during storage. Drying at low temperature led to increased water content in the powders which resulted in higher stickiness and reduced the amount of free-flowing powder (Toro-Sierra et al., 2013).

The influence of inlet air temperature on the powder density was depicted in Figure 1C. Trends of decreasing both bulk and tapped density with the increase in inlet air temperature were due to faster evaporation rates leading to a more porous or fragmented structure (Goula & Adamopoulos, 2012) and reduction of moisture content (Hedayatnia et al., 2016). Lower inlet drying air temperature provided lower rate of evaporation, thus giving more time for diffusion and rearrangement of the solids dissolved in the droplet resulting in denser particles (von Halling Laier et al., 2019). Similar trends were also observed in the previous investigation conducted by (Abdullah et al., 2021). The tapped density was higher compared to bulk density due to the act of tapping increasing the compactness of particle packing and diminishing the volume among particles. Tapped density has become more applied for storage and transportation of powder products.

The average particle size tended to increase with the increase in inlet air temperature (Figure 1D). This was confirmed by previous investigation (Goula & Adamopoulos, 2012). The remarkable big particle size was observed at high drying air temperature of 180°C. This could be due to trapped water vapor inside the particles expanding the volume and particle size. Moreover, the average particle size dried with air at 110°C was larger than that dried at 130°C. Possibly, the particles were agglomerated due to the higher moisture content since evaporation occurred at a much slower rate at lower temperature. Additionally, the water vapor in the drying air could be easily condensed at a temperature as low as 110°C triggering agglomeration among the particles.

Interestingly, the rehydration time of VCO powder was increasing with the inlet air temperature increase as could be seen in Figure 1E. This was aligned with the previous investigation (Salimi et al., 2018). Many factors could influence the rehydration time such as drying conditions, particle size distribution, moisture content, temperature, component degradation and so on. The rehydration time of the powder dried at 150°C was almost similar with that dried at 130°C, which was about 5 minutes. The rehydration time could become an important parameter to be considered for the reconstitution of VCO powder. The pH values of reconstituted VCO powder in aqueous solution were in the range of ~ 7.6 - 7.9 (Figure 1F) with the varying inlet air temperatures, which were within the acceptable normal pH.

Flowability properties were of high importance for powdered materials. They were measured using Carr's index (%CI) and Hausner ratio (HR) indicating the flow characteristics and cohesiveness, respectively (Mahdi et al., 2020). All %CI and HR of all samples (T110, T130, T150, and T180) could be seen in Table 3. The CI percentage of sample

T110 was <20% and Hausner ratio (HR) was in the range of 1.19-1.25 indicating fair flowability, whereas samples T130, T150, and T180 demonstrated passable flowability with %CI within 21-25% and HR within 1.26-1.34 (Saifullah et al., 2016). Sample T110 dried by air entering at 110°C showed a slight better flowability despite of its agglomerated particles. Base on this study, all powders were considered to be flowable due to passable cohesiveness among particles independent of inlet drying air temperature.

The morphology of inulin-coated VCO powder prepared at different drying temperature could be seen in Figure 2. It was obvious that sample T150 prepared at drying temperature 150°C demonstrated the best morphology of inulin-coated VCO powder with spherical appearance and without significant particle agglomeration. Sample T180 showed several big particles with coarse surfaces indicating that some fissures or cracks could be present. Besides that, some small particles were adhered and sticky to big particles (O'Donoghue et al., 2019). These coarse surfaces were formed due to a fast rate drying impeding water removal. The water vapor inside the particle could create high pressure thus explode into the surface leaving some fissures or crack which could reduce encapsulation efficiency (Abdullah et al., 2021; Goula & Adamopoulos, 2012) although spherical particle appearances were still dominant. Morphology of VCO powder prepared under 150°C demonstrated a larger extent of particles agglomeration. Particle bridges were obviously seen in sample T110 demonstrating a massive stickiness over the particles. The drying air temperature of 110°C was not sufficient to extensively evaporate water thus quite high moisture content was still retained in the particles causing agglomeration leading to stickiness.

3.2 Effect of feed flow rate, aspiration rate, and air pressure at nozzle on inulin-coated VCO powder characteristics

Influences of other drying process parameters such as feed flow rate, aspiration rate, and air pressure at nozzle on VCO powder characteristics could be seen in Table 2. Emulsion feed flow rates of 5 ml/min and 8 ml/min (sample T150 *vs.* F08) were compared. As feed flow rate was increased to 8 ml/min, the powder yield was decreased and the moisture content was increased. This inferred the lack of drying time as the powder went down to the bottom of the drying chamber column due to a shorter residence time. The feed rate needed to be adjusted to ensure that each droplet reached the desired drying level before it comes in contact with the surface of the drying chamber (Gharsallaoui et al., 2007; O'Sullivan et al., 2019). The increased moisture content led to decrease in powder yield due to enhanced stickiness among the particles. On the other hand, time required for rehydration was decreased. Furthermore, the particle size was increased with the increase in feed rate which was in line with (Gharsallaoui et al., 2007). The formation of crust layer was retarded in larger particle size, thus there was possibility of oil leaching into the surface, lowering the encapsulation efficiency (Geranpour et al., 2020). The droplets produced from the atomizer should be not too large or too small. The droplet may not be dried completely if the droplet is too large, and vice versa, the recovery of dried product is difficult and may get over heat and become scorched when the droplet is too small (Mounika et al., 2021).

When aspiration rate was decreased from 100% to 80% (sample T150 *vs.* A80), similar tendency as the increased feed flow rate was observed. Basically, the powder drying time in the column was increased as aspiration rate or drying air rate was decreasing. High aspiration rate would increase the evaporation rate and water transfer from the droplet surface to the drying air besides it might help improve the separation efficiency of fine particles in the cyclone. The decrease in aspiration rate resulted in lower yield due to increased moisture content of the particles enhancing their proneness to sticking.

The effect of air pressure increase from 1 bar to 1.8 bar (sample T150 *vs.* P18) resulted in a much decrease in average particle size which was in line with the previous investigation (Salimi et al., 2018; Wang et al., 2019).The increased air pressure tended to lower droplet size due to increased energy for the droplets to overcome the surface tension and viscous force (O'Sullivan et al., 2019; Wang et al., 2019). Additionally, air atomizing pressure could deliver good atomization effect and lowering the possibility of clogging (Wang et al., 2019). However, the powder yield was reduced and moisture content was increased with the increase in air pressure. The air pressure was probably too high thus producing fine particles. The fine particles possessed a greater surface area responsible for water uptake during the powder collection enhancing stickiness and lowering powder yield. The selection of air supply pressure on atomization should not be too high or too low (Wang et al., 2019).

The pH values of 10% VCO powder in aqueous solution ranged from ~7.7 - 7.9 and were within the acceptable normal pH. Furthermore, %CI and HR of T150, F08, A80, and P18 samples demonstrated passable flowability indicating passable flow behavior independent of feed rate, aspiration rate, and air pressure at nozzle used in this study.

3.3 Effect of total solid percentage on inulin-coated VCO powder characteristics

Total solid percentage (%TS) in the feed O/W emulsion definitely affected the drying process and also the characteristics of VCO powder. Various total solids (45, 50, and 55%) of the O/W emulsion were prepared and spray dried using several fixed drying process parameters, i.e., inlet air temperature 150°C, feed flow rate 5 ml/min, aspiration rate 100%, and air pressure at nozzle 1 bar. The highest yield was obtained at 50%TS as depicted in Figure 3A. This highest yield was also reflected by its lowest moisture content (Figure 3B) indicating reduced potential stickiness among particles. The evaporation rate from the droplet surface was decreased following the increasing feed viscosity due to higher fraction of polymers present in the solution (O'Sullivan et al., 2019) which explained the higher moisture content of particles prepared at 55% TS after drying. At lower feed concentration, smaller particles were tended to form. However, the tendency of particle agglomeration was higher in fine particles due to their tendency to draw water thus lowering the obtained yield.

Even though higher %TS was expected in order to reduce the energy consumption for water removal, a much higher %TS would increase the viscosity which would increase the friction of molecules in the nozzle and retard the droplet formation. Furthermore, larger droplet was generally formed when more viscous concentrated solution was atomized, resulting in larger powder particles (O'Sullivan et al., 2019). However, average particle size of sample TS55 was much smaller than that prepared at 50% TS (Figure 3D). This result was probably affected by the applied vibration during sieving process resulting in particle collision leading to particle size reduction. Furthermore, particle density was increased with the increased %TS (Figure 3C) which was in line with the previous investigation (Quispe et al., 2020). Higher concentration of solid materials in the feed tended to improve the compactness of obtained powder.

Furthermore, the functional properties of VCO powder were measured by the rehydration time and pH (Figure 3E and 3F). The rehydration time of sample prepared at 50%TS was a bit higher than others prepared at 45% and 55% TS. The pH values of the reconstituted VCO powder were within ~7.6 – 7.9 with the variations of %TS which were within the acceptable normal pH for further applications. Moreover, the samples prepared at 45% and 50% TS showed passable flowability based on %CI and HR whereas the sample prepared at 55% TS demonstrated poor flowability since %CI were in the range of 26-31 and HR ranged from 1.35-1.45 (Saifullah et al., 2016). It turned out that concentrated O/W emulsion feed could have a detrimental effect on the powder flow behavior due to increased cohesiveness among the particles.

The morphology of inulin-coated VCO powders obtained with varying %TS could be seen in Figure 4. It was obvious that the particles obtained at 45% TS and 55% TS demonstrated a higher extent of agglomeration in inulin-coated VCO powder. Very less particles were aggregated in the sample prepared at 50% TS. This again confirmed that the highest yield obtained at the feed concentration of 50% TS was contributed by the low degree of particle stickiness.

4. Conclusion

The inulin-coated VCO powder with a lot of health benefits was quite potential to be used as ingredients for the development of functional food products. The inulin-coated VCO powder produced by spray dryer with high yield and desirable characteristics was highly dependent on the process parameters as well as feed formulation. The process parameters with inlet air temperature 150°C, feed flow rate 5 ml/min, aspiration rate 100%, air pressure at nozzle 1 bar and emulsion feed with 50% total solid successfully delivered powder products with the highest yield of ~88%, lowest moisture content of 2.9%, and demonstrated the least agglomerated particles based on SEM analysis. There could be complex interactions among numerous factors such as drying process parameters, feed formulation, and the properties of components in the feed which dictated the final characteristics of VCO powder. The increase in inlet air temperature tended to increase yield and lower the moisture content due to a higher evaporation rate. However, the opposite trends were observed when too high inlet air temperature was applied due to early crust formation on the surface hindering water removal process. Furthermore, yield was tended to decrease with the feed flow rate increase, aspiration rate decrease, and air pressure increase due to a much higher moisture content confirmed by a higher extent of particle agglomeration. The total solid concentration in the emulsion feed modulated the feed viscosity which would in turn affect the atomization process. It turned out that total solid of 45% and 55% produced lower yields with higher degree of agglomerated particles compared to feed emulsion with 50% TS. Stickiness was commonly occurred in the powdered materials due to liquid bridging leading to agglomerated particles resulting in the unexpected yield reduction.

Furthermore, the average pH of reconstituted VCO powder of ~7.8 was within the normal range and the average rehydration time of ~ 5 minutes seemed to be well accepted for further applications in both food or beverages industries. The inulin-coated VCO powder demonstrated passable flowability based on %CI and HR for all experimental variations except that prepared using 55% TS which showed poor flowability due to stronger cohesiveness presents in the particles. The inherent components properties of biopolymers used in the formulation also played significant role in determining the final powder characteristics which should be further investigated. A more comprehensive study related to the drying process optimization in relation with the encapsulation efficiency of VCO combined with economic analysis was recommended for enabling inulin-coated VCO powder production at a large scale.

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Conflict of Interest

The authors have declared that no conflict of interest exists.

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Figure

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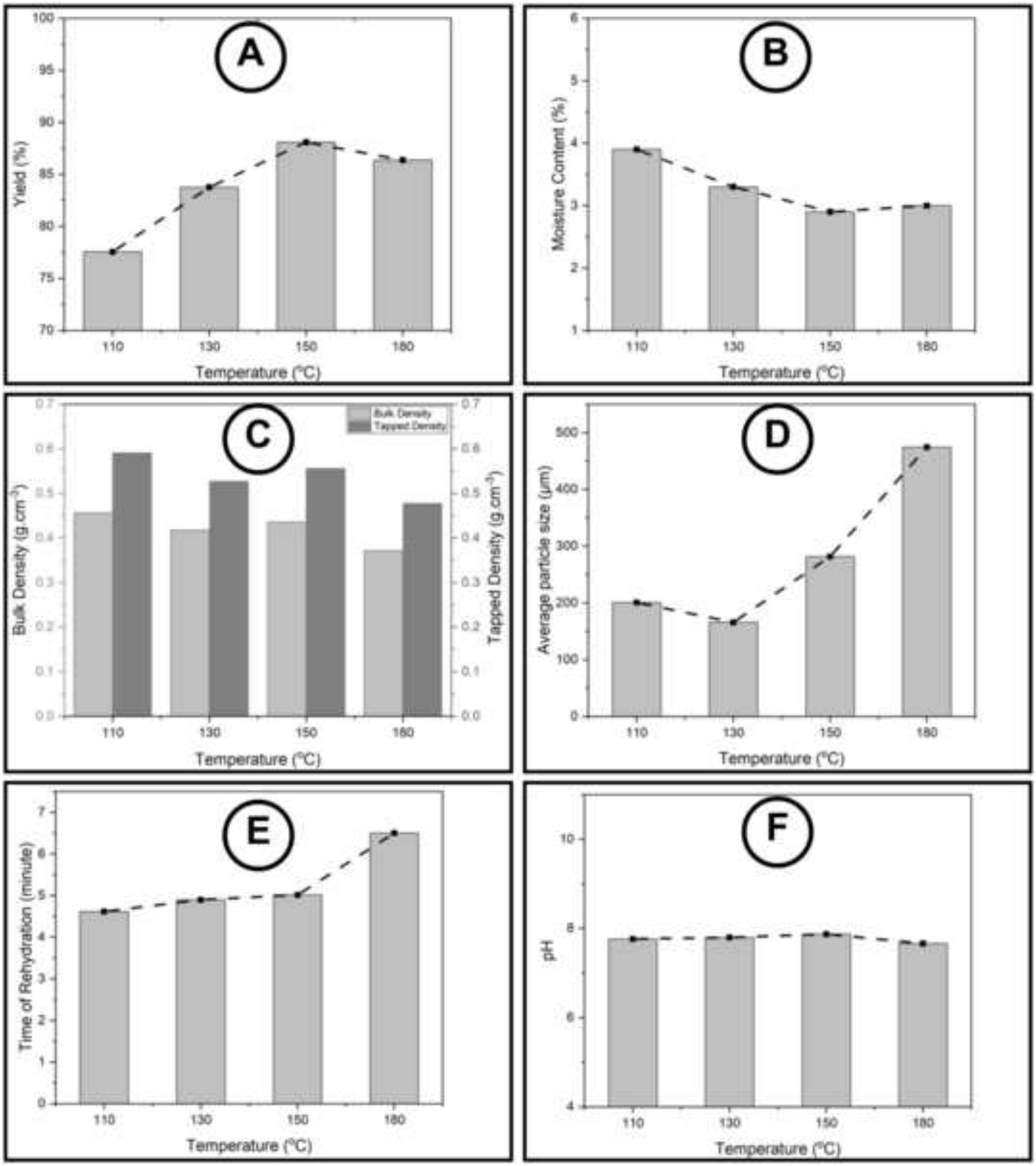

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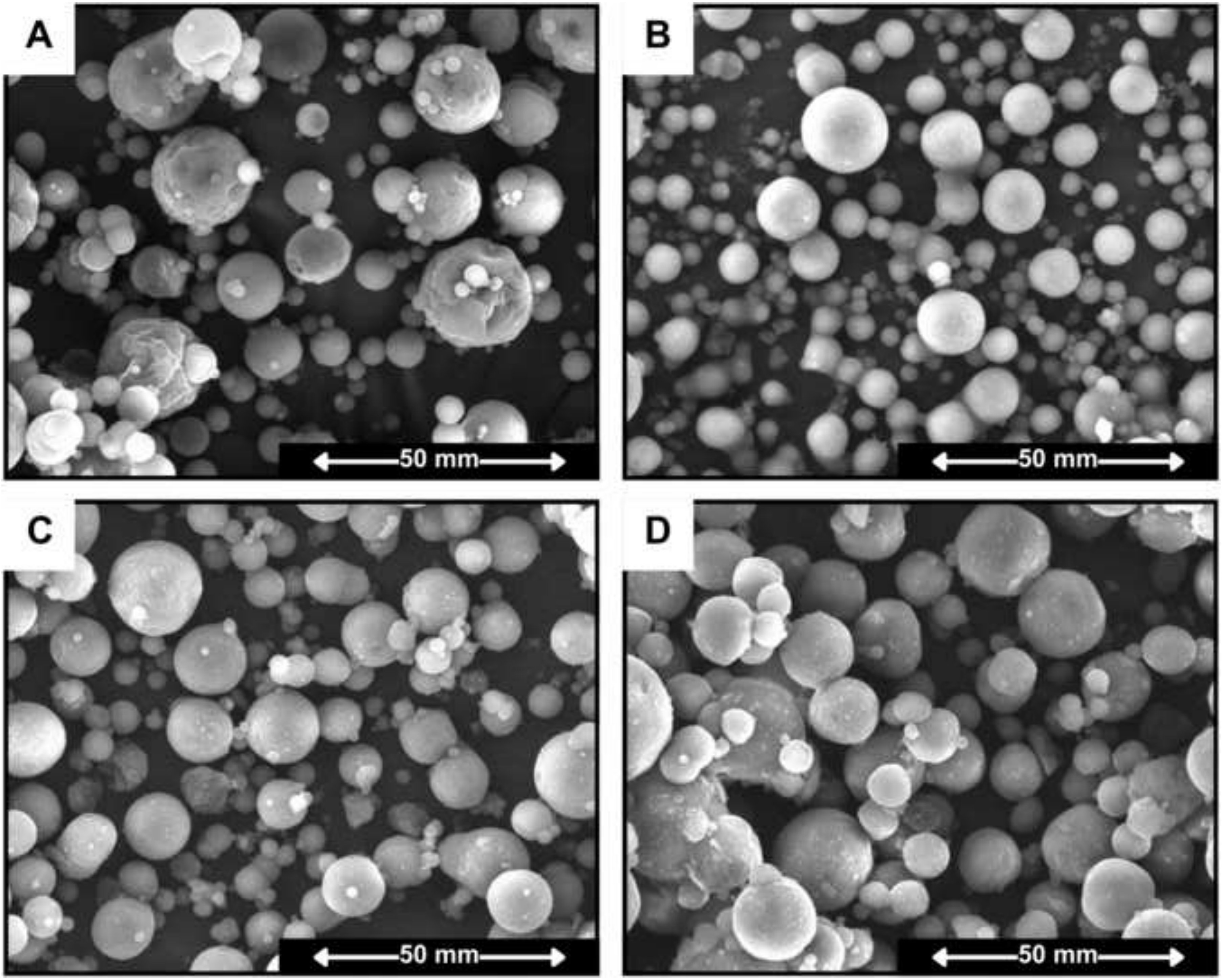

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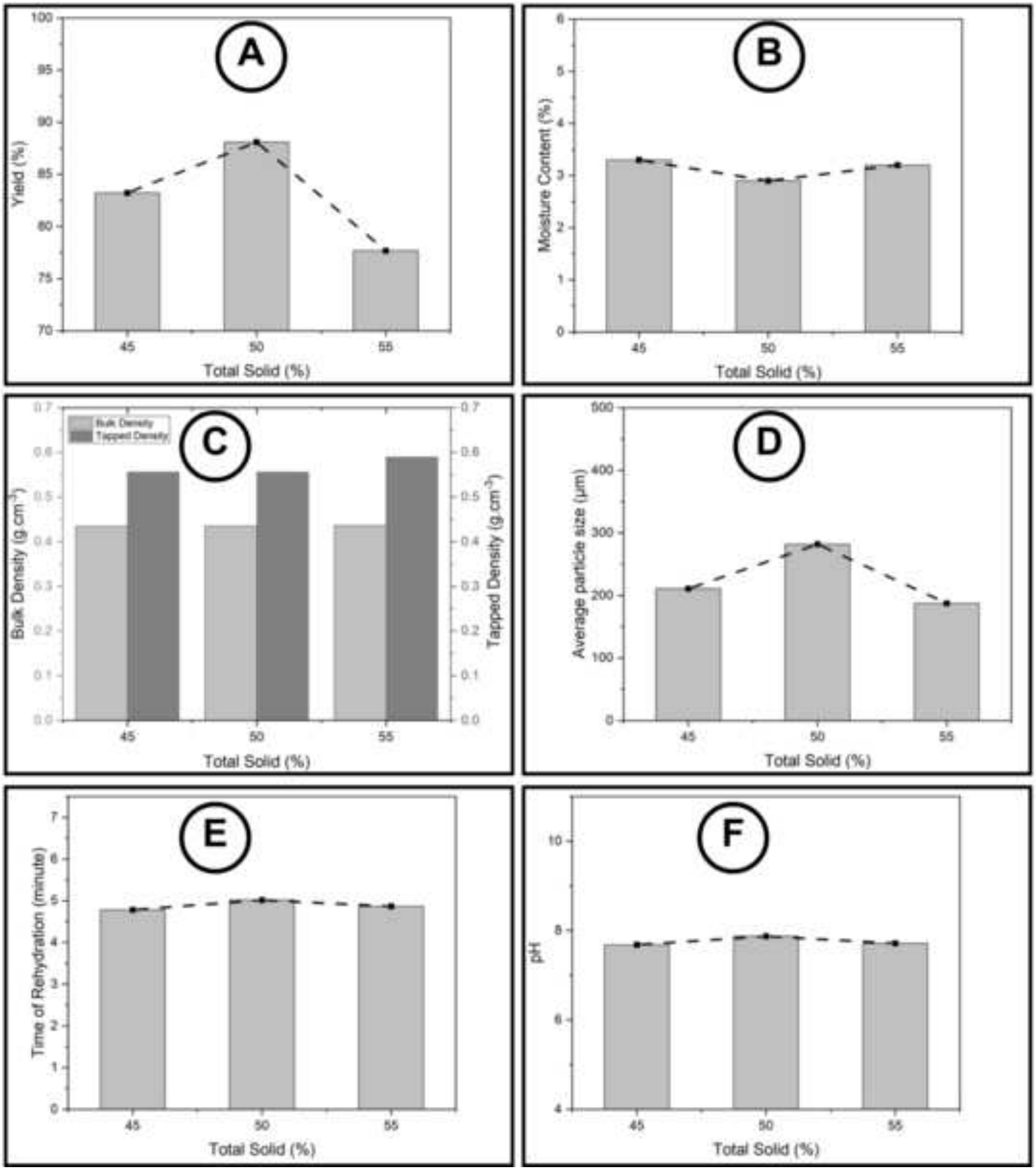

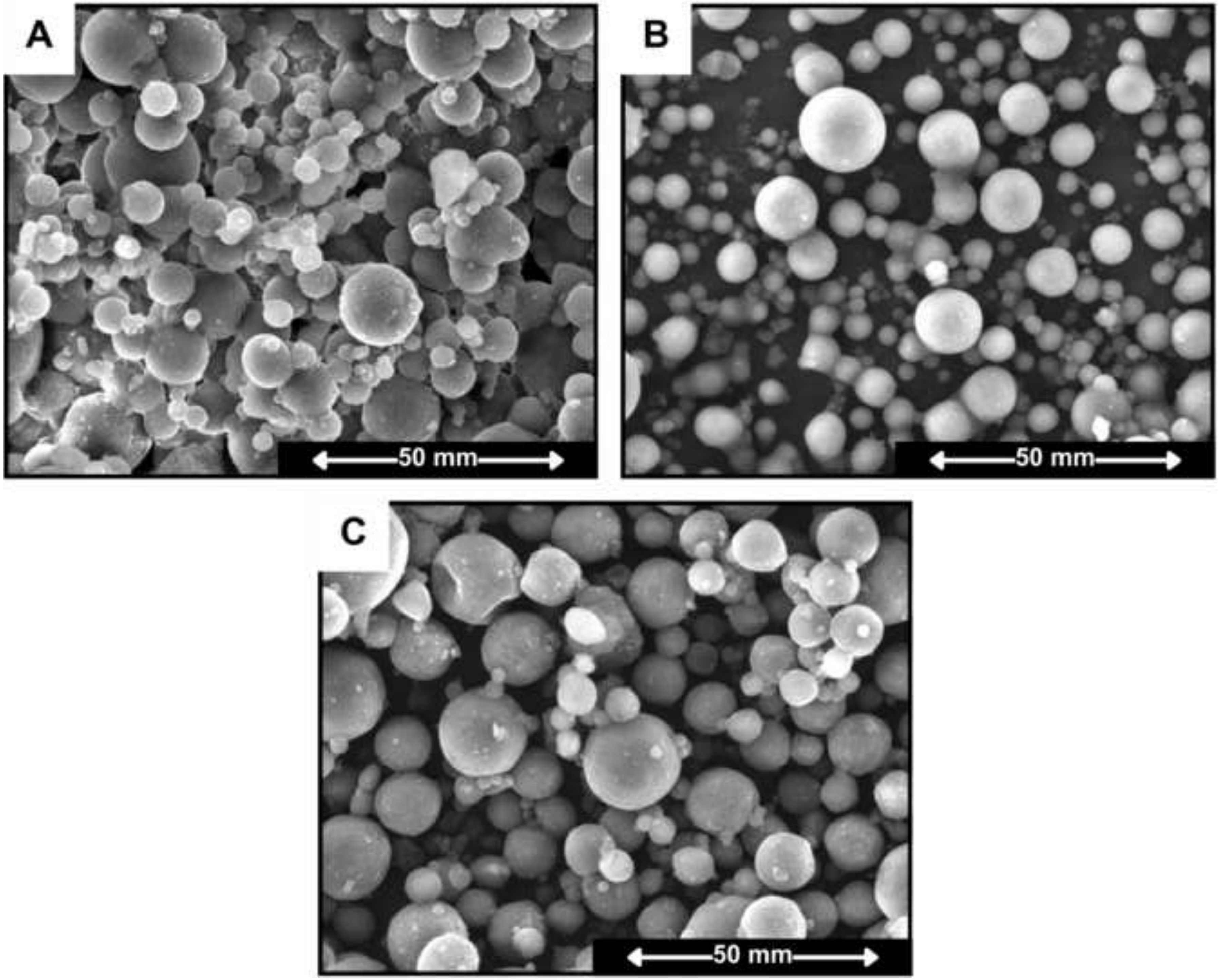
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Figure captions

Figure 1. The influences of inlet air temperatures on powder characteristics. A) Yield; B) Moisture content; C) Bulk and Tapped density; D) Average particle size; E) Time of rehydration; F) pH of 10% powder in aqueous phase. The other process parameters such as feed flow rate (5 ml/min), aspiration rate (100%), air pressure at nozzle (1 bar), and total solid percentage in the feed (50%), were kept constant.

Figure 2. Scanning electron micrographs of inulin-coated VCO powder dried at different drying air temperature. A) 180°C; B) 150°C; C) 130°C; D) 110°C. The other process parameters such as feed flow rate (5 ml/min), aspiration rate (100%), air pressure at nozzle (1 bar), and total solid percentage in the feed (50%), were kept constant.

Figure 3. The influences of total solid percentage in emulsion feed on powder characteristics. A) Yield; B) Moisture content; C) Bulk and Tapped density; D) Average particle size; E) Time of rehydration; F) pH of 10% powder in aqueous phase. The other process parameters such as inlet air temperature (150°C), feed flow rate (5 ml/min), aspiration rate (100%), and air pressure at nozzle (1 bar), were kept constant.

Figure 4. Scanning electron micrographs of inulin-coated VCO powder prepared at different total solid percentage in the emulsion feed. A) 45%; B) 50%; C) 55%. The other process parameters such as inlet air temperature (150°C), feed flow rate (5 ml/min), aspiration rate (100%), and air pressure at nozzle (1 bar), were kept constant.

Table 1. The Overall Experimental Variations

Sample	Inlet Air Temperature (ºC)	Feed flow rate (ml/min)	Aspiration rate (%)	Air Pressure at Nozzle (bar)	Total Solid (%)
T180	180	5	100	1	50
T150	150	5	100	1	50
T130	130	5	100	1	50
T110	110	5	100	1	50
A80	150	5	80	1	50
P18	150	5	100	1.8	50
F08	150	8	100	1	50
TS45	150	5	100	1	45
TS55	150	5	100	1	55

Note: The sample code T was assigned for the variation in inlet air temperature; A for the variation in aspiration rate; P for the variation in air pressure at nozzle; F for the variation in feed rate; and TS for the variation in total solid

Table 2. Inulin-coated VCO powder characteristics

Sample	Yield (%)	Moisture content (%)	Bulk density (g/cm^3)	Tapped density (g/cm^3)	Average particle size (μm)	pH	Time of Rehydration (minute)
T180	86.38	3.0	0.3714	0.4776	474.45	7.662	6.500
T150	88.10	2.9	0.4351	0.5559	281.84	7.873	5.016
T130	83.76	3.3	0.4173	0.5272	165.88	7.797	4.900
T110	77.55	3.9	0.4668	0.5735	200.60	7.765	4.616
A80	87.50	3.2	0.4320	0.5457	315.72	7.839	4.950
P18	85.65	3.3	0.4438	0.5794	201.33	7.725	4.800
F08	86.01	3.5	0.4170	0.5267	295.29	7.726	4.916
TS45	83.23	3.3	0.4349	0.5557	210.64	7.683	4.783
TS55	77.67	3.2	0.4359	0.5897	187.54	7.713	4.866

Table 3. Flowability properties of inulin-coated VCO Powder

Sample	Carr's index (%)	Hausner ratio	Flowability
T180	22.24	1.29	passable
T150	21.73	1.28	passable
T130	20.85	1.26	passable
T110	18.61	1.23	fair
A80	20.84	1.26	passable
P18	23.40	1.31	passable
F08	20.83	1.26	passable
TS45	21.74	1.28	passable
TS55	26.08	1.35	poor

Highlights

- Novel production of VCO powder encapsulated with inulin using spray drying technology for health-conscious consumer markets
- Study of the influence of spray drying process parameters (inlet air temperature, feed flow rate, aspiration rate, air pressure at nozzle), and feed concentration on powder characteristics
- Powder characteristics include bulk density, tapped density, particle size, flowability properties, and morphology
- The properties of reconstituted VCO powder were studied in terms of pH and time of rehydration

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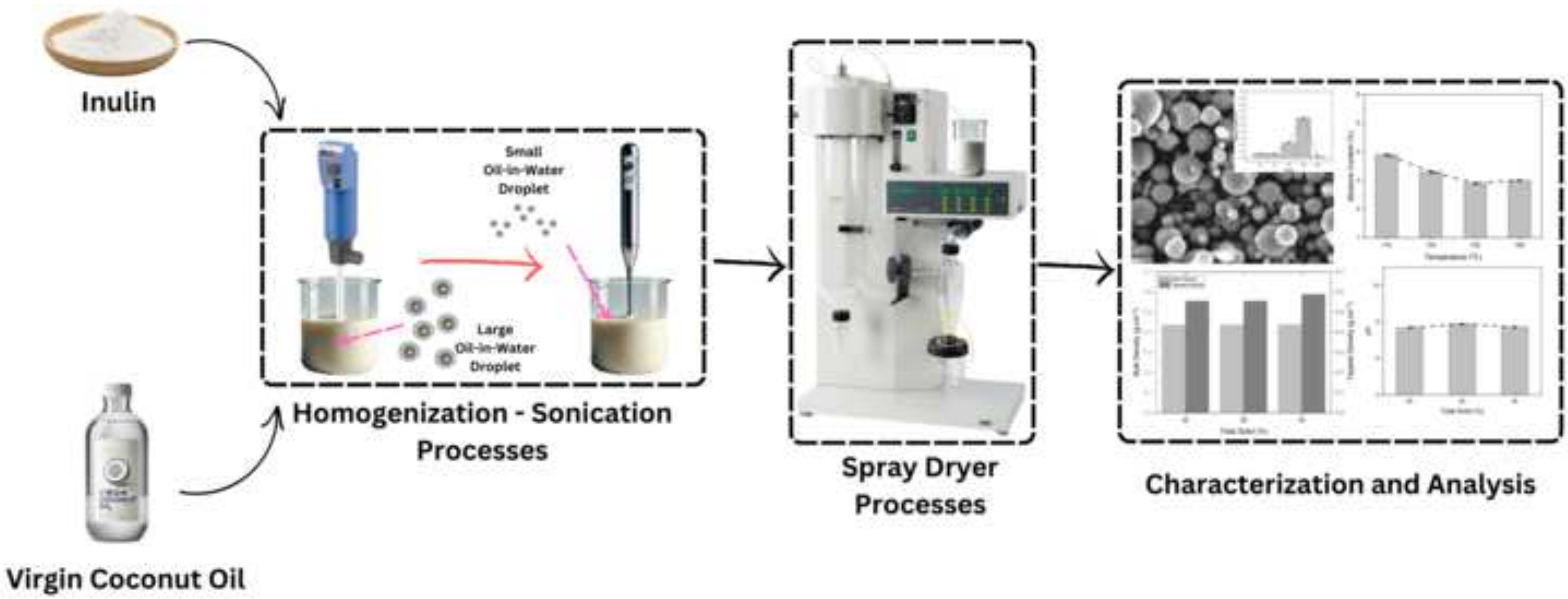

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Editor and Reviewer Comments:

Reviewer 1: The manuscript titled Inulin-coated Virgin Coconut Oil (VCO) Powder Produced by Spray Drying is truly a good piece of work, which, with minor revisions, is suitable for publication in such a prestigious journal. Below are my comments and questions for the authors.

The last sentence in the abstract is somewhat weak and probably purposeless at this point. Please improve it.
The last paragraph of the introduction definitely needs improvement; please rewrite it and make the objective of this work clearer.
"The drying air temperature of 110°C was not sufficient to extensively evaporate water, thus quite high moisture content was still retained in the particles, causing agglomeration leading to stickiness." — So why didn't you change the temperature?
"Furthermore, %CI and HR of T150, F08, A80, and P18 samples demonstrated passable flowability..." — but what does this imply?
Conclusion — the last paragraph should be shortened; it's understood that you'll be working on something in the future, so there's no need to write such meaningless statements.
Figure 1 — very unclear. Please improve it.
Figure 3 — same issue.
In summary, it should be emphasized once again that this is a good piece of work.

3

Reviewer 2: This article reports the investigation of the spray drying of coconut oil using Inulin as wall material. The manuscript is well written, methods are solid and results are interesting and new. I thus, recommend it for publication after some minor issues have been consider.

Minor comments
Error bars should be provided for figures 1 and 3
There is no figure 2 D, although it is mentioned in the captions and in the results section (The missing micrograph corresponds to 110° C Spray Drying Temperatue)
Section 3.3 Last paragraph. Delete the word "Very"

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